ATIS and Commuters Behavior: Factors Affecting Behavioral Intentions Toward the Use of Travel Information Technology

Mehdizadeh Dastjerdi, Aliasghar

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ATIS and Commuters Behavior: Factors Affecting Behavioral Intentions Toward the Use of Travel Information Technology

Aliasghar Mehdizadeh Dastjerdi

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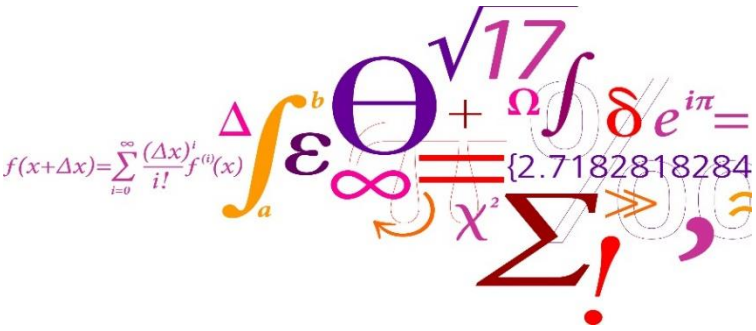

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Author:	Aliasghar Mehdizadeh Dastjerdi
Supervisors:	(Co) Sigal Kaplan, (Main) Francisco Camara Pereira
University:	Technical University of Denmark
Department:	DTU Management Engineering
Division:	
Address:	Produktionstorvet Building 358 DK-2800 Kgs. Lyngby www.man.dtu.dk
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In memory of my father
To my wife, and my mother
With love and eternal appreciation

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Aliasghar Mehdizadeh Dastjerdi, December 2018

SUMMARY

Transport activity has a range of negative effects including congestion, air pollution, CO2 emissions and accidents. Furthermore, the increasing complexity and demand of transport services strains transportation systems especially in urban settings with limited possibilities for building new infrastructure. Such transport–related issues have urged the need for encouraging sustainable urban mobility. While technological advances can alleviate these issues, it is widely recognized that changing travel behavior can be more important in achieving modal shift i.e. from car use to active mode or public transport.

In recent years, one of the solutions that have received a lot of attention to motivate change for sustainable urban mobility is information dissemination and persuasion delivered through mobility-management travel apps, also known as persuasive technology. They have gained popularity in interventions to change users attitude/behavior through providing health and environmental feedback, tailoring travel options, self-monitoring, tunneling users toward green behavior, social networking, nudging and gamification elements. However, their influence to promote sustainability depends mostly on how individuals react to them and adapt their behavior. More specifically, their efficacy highly depends on understanding the underlying mechanisms and processes of behavior change, i.e., why and how behavior change occurs and what driving forces and determinants guide behavior.

This PhD study aims at creating a better understanding of the motivators and barriers for persuasive travel apps market penetration, which will aid relevant stakeholders to design effective and appealing system, eventually translating into wider potential of sustainable mobility behavior. This study investigates the contributing factors to the use of a multi-faceted mobile app including both multimodal real-time traffic information and persuasive features. Most of the research regarding information technologies concerns their prospective impact and literature review revealed a lack of understanding about how individuals are motivated to accept and adopt mobility-management travel apps. Furthermore, there is a lack of sufficient attention to explain users' behavior of the travel apps with support from behavioral theories. The main contribution of this PhD study is to provide knowledge of critical aspects when considering persuasive features for the purpose of sustainable mobility. It is achieved through behavioral theories, establishing theoretical frameworks and considering users perspective. This contributes to a better explanation of the user-sided heterogeneity, and accordingly to move away from the concept of "one size fits all" solution.

In this context, Alderfer's ERG model of human needs, Lindenberg's goal-framing theory, and Bandura's triadic reciprocal determinism were employed in order to accomplish a well-founded research in behavioral theories. The theoretical frameworks were developed based on the above mentioned behavior theories and tested empirically using three different technology preference datasets collected specifically for this purpose. Structural equation modeling (SEM), Bayesian structural equation modeling (BSEM) and Max-Min Hill-Climbing (MMHC) for discovering causal structure were used to analyze the collected data.

The findings revealed that users could exhibit different behaviors according to socio-economic characteristics, travel habits, attitudinal factors etc. Therefore, the motivations for choices are specific to individual users and depend on wide-ranging factors that go beyond traditional economic and socio-demographic methods. The findings showed the importance of non-monetary motives in influencing the use of persuasive features of mobility-management travel apps. However, the results highlighted the domination of self-interest motives of trip efficiency improvement for the adoption intention. It was revealed that the barriers embedded in the functions of the travel app negatively influence its adoption. In this regard, the two dimensions influencing the appraisal of acceptance of the app, relate with low usage risk and high usability. The findings showed that technophiles are an important target user group of mobility-management travel apps. The results indicated the importance of pro-environmental attitude and responsibility since they not only develop non-monetary values of using mobility-management travel apps, but also foster users' engagement and attraction. The findings also suggested the importance of social dynamics behind the information system in influencing users' attitude and behavior. More specifically, people's emotional connections with the city, their trust on each other and on transport organizations play an important role in the attraction and engagement.

RESUME (DANISH)

Transportaktivitet har en række negative virkninger, herunder trængsel, luftforurening, CO2-emissioner og ulykker. Desuden stiger den stigende kompleksitet og efterspørgsel af transporttjenester især i byområder med begrænsede muligheder for at udbygge ny infrastruktur. Sådanne transportrelaterede udfordringer har skabt behovet for at fremme bæredygtig mobilitet i byerne. Mens teknologiske fremskridt kan lette disse problemer, er det almindeligt anerkendt, at skiftende rejseadfærd kan være vigtigere for at opnå modalskifte, dvs. fra bilbrug til cykel og gang eller offentlig transport.

I de senere år har en af løsningerne til at motivere forandringerne til bæredygtig bymobilitet, der har fået stor opmærksomhed, informationsformidling og overtalelse, der leveres via mobilitetsstyrings-rejse-apps, også kendt som *persuasive* teknologi. De er blevet populære som interventioner for at ændre brugerens holdning og adfærd ved at give feedback ift. sundhed og miljø, skræddersy rejsemuligheder, selvovervågning, overbevisning af brugere mod grøn opførsel, sociale netværk, *nudging* og *gamification* elementer. Men deres indflydelse på at fremme bæredygtighed afhænger hovedsageligt af, hvordan enkeltpersoner reagerer på dem og tilpasser deres adfærd. Nærmere bestemt afhænger deres effektivitet meget af forståelse af de underliggende mekanismer og processer for adfærdsændring, dvs. hvorfor og hvordan adfærd ændrer sig, og hvilke drivkræfter og determinanter der leder adfærd.

Denne PhD-undersøgelse har til formål at skabe en bedre forståelse af motivationer og hindringer for markedsindtrængning af *persuasive* rejse-apps, som vil hjælpe relevante interessenter med at designe et effektivt og tiltalende system, og dermed kunne resultere i et bredere potentiale for bæredygtig mobilitetsadfærd. Denne afhandling undersøger de bidragende faktorer til brugen af en mobil app, der omfatter både multimodal realtidstrafikinformation og overbevisende funktioner. Det meste af forskningen vedrørende informationsteknologier omhandler deres fremtidige indflydelse og litteraturstudie afslørede, at der mangler viden om, hvordan enkeltpersoner er motiverede til at acceptere og anvende mobilitetsstyrende rejse-apps. Derudover er der i litteraturen ikke tilstrækkelig opmærksomhed på brugernes adfærd i rejse-appen ift. adfærdsteorier. Hovedformålet med dette PhD-afhandling er at skabe ny viden om kritiske aspekter, når man overvejer overbevisende egenskaber med henblik på bæredygtig mobilitet. Det opnås gennem adfærdsteorier og etablering af teoretiske rammer med udgangspunkt i brugerens perspektiv. Dette bidrager til en bedre forklaring af den brugersidede heterogenitet for dermed at bevæge sig væk fra en "one size fits all"-løsning.

I denne sammenhæng blev Alderfers ERG-model af menneskelige behov, Lindenbergs målramningsteori og Banduras triadiske gensidige determinisme anvendt for dermed at basere afhandlingen på velbegrundet forskning i adfærdsteorier. De teoretiske rammer blev udviklet ud fra ovennævnte adfærdsteorier og testet empirisk ved hjælp af tre forskellige datasæt om teknologipreferencer, indsamlet specifikt til dette formål. Structural Equation Modeling (SEM), Bayesian Structural Equation Modeling (BSEM) og Max-Min Hill-Climbing (MMHC) blev brugt til at analysere de indsamlede data for at undersøge den kausale struktur.

Resultaterne viste, at brugerne kunne udvise forskellige adfærd i forhold til socioøkonomiske egenskaber, rejsevaner, holdningsfaktorer mv. Motivationen bag de enkelte brugeres valg er der derfor person-speficikke og afhænger af omfattende faktorer, der går ud over traditionelle økonomiske og sociodemografiske metoder. Resultaterne viser betydningen af ikke-monetære motiver i at påvirke brugen af *persuasive* træk ved mobilitetsstyringsrejse-apps. Resultaterne understreger dog, at personlige motiver ift. rejseforbedringer er dominerende i forhold til at anvende app'en. Det blev afsløret, at de hindringer, der er indlejret i rejse-appens funktioner, negativt påvirker dets vedtagelse. I den henseende er de to dimensioner, der påvirker accepten af appen, forbundet med lav brugsrisiko og høj anvendelighed. Resultaterne viser, at technophiler er en vigtig målbrugergruppe af mobilitetsstyringsrejse-apps. Resultaterne viser betydningen af holdning og ansvar overfor miljø, da de ikke kun udvikler ikke-monetære værdier for at bruge mobilitetsstyringsrejse-apps, men også fremmer brugernes engagement og tiltrækning. Resultaterne tyder også på vigtigheden af sociale dynamikker bag informationssystemet for at påvirke brugernes holdning og adfærd. Mere specifikt spiller folks følelsesmæssige forbindelser til byen, deres tillid til hinanden og til transportorganisationer en vigtig rolle i tiltrækningen og engagementet.

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1. Introduction

Current transport systems suffer from a number of challenges, such as traffic congestion, accident, air pollution and greenhouse gases (GHG) emissions. The environmental impact of transport systems is substantial since the transport sector is highly dependent on fossil fuels and responsible for 19% and 23% of global energy consumption and CO2 emissions respectively (IEA, 2014). Urban travel currently accounts for more than 60% of total kilometers travelled worldwide; as a consequence, urban transport is the largest contributor to global transport-related carbon emissions and the main source of local air pollution (Rode et al., 2017).

For Denmark, energy consumption in the transport sector accounts for one-third of total Danish energy use and is almost exclusively based on fossil fuels. The share of fossil fuels in total energy used by the transport sector is 95% which is directly reflected in its CO2 emissions (Danish Energy Agency, 2018). Road transport consumes the largest amount of energy. Passenger vehicles are a major pollution contributor and they are responsible for almost half of CO2 emitted from road transport (The Danish Government, 2013).

Considering these problems and the negative impacts of transport in urban settings, different policy instruments have been suggested and implemented for reducing travel demand and increasing the efficiency of transport capacity. In this context, Headicar (2009) separated the policy instruments for sustainable transport planning into four overarching groups based on their specific targets. They are categorized as “Economic and fiscal policies”, “Physical land use and development policies”, “Transport management policies”, and “Technology policies”. Figure 1-1 displays the four groups of policies and their components. While the forms and focuses of the suggested policies are different, they seek for achieving the same goal: “to make the most efficient use of the available transport infrastructure and to use the most appropriate technology available to minimize resource consumption” (Banister, 2005).

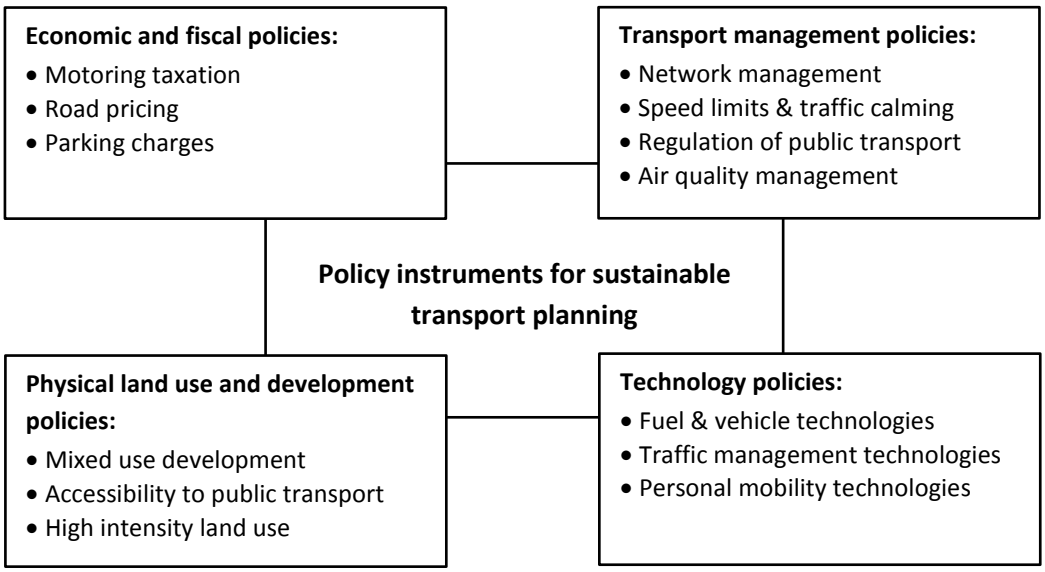


Figure 1-1 Policy instruments and their components for sustainable transport planning

The influence of policy measures to promote sustainability depends mostly on how people react to them and adapt their behavior. For urban transport, the achievement of better sustainability requires changes in mobility behavior, i.e., shifting from car use to public transport and active modes as highlighted by prior studies (e.g., Bamberg et al., 2011; Hiselius and Rosqvist, 2016). In recent years, policy measures focusing on car use reduction through information dissemination and persuasion have attracted increased attention. They emerged as the concept of Mobility Management (MM), in Europe, Australia, and Japan, and often referred as soft measures aiming at supporting voluntary travel behavior changes (VTBC) in car use (Cairns et al., 2008; Taniguchi et al., 2007; Van Acker et al., 2013).

Traditional VTBC solutions require person-based interaction, either by phone or home interviews, which is inherently expensive and may induce biases stemming from social interaction and communication. The proliferation of information and communication technologies (ICT) has provided new opportunities for drawing on technology applications to assist VTBC programs. They are intended to deliver information influencing individual awareness of the need for environmentally sustainable travel behavior. These information-based tools, besides their low-cost to decision makers and wide availability to the general public, are potentially powerful from the behavioral perspective. Problem awareness affects perceived responsibility, behavioral control and social norms. These, in turn, affect behavioral intentions and actions (Bamberg et al., 2011; Eriksson et al., 2006). Hence, information technologies are important tools in leading toward sustainable travel behavior. As they belong to commitment-oriented strategies, they are also more likely to be implemented owing to their political acceptability (Gärling et al., 2004). They do not involve the ethical and normative issues which usually impede the public acceptance of pricing or monetary reward schemes (Di Ciommo et al., 2013; te Brömmelstroet, 2014). They encourage informed decisions, thus encouraging people to make a rational choice based on costs and benefits (Steg and Vlek, 2009), and make "the right choice for the right reasons" thus satisfying higher-order emotional needs of self-actualization that are important in long-term behavioral shifts (te Brömmelstroet, 2014).

Recently, the application of portable electronic devices (e.g., mobile phone, smartphone, laptop) as a platform for implementing MM actions has been put forward as a novel policy for improving urban sustainability (Semanjski et al., 2016). Prior studies have investigated their practical application for traffic data collection and proved their effectiveness (e.g., Araghi et al., 2015; Stipancic et al., 2018; Strauss et al., 2017; Vlassenroot et al., 2015). The application of mobile phones/smartphone assisted VTBC is an active area of research; however, it is still in its infancy. Some examples of prototypes intended to influence mobility behavior can be given by: SUPERHUB (Gabrielli and Maimone, 2013), IPET (Meloni et al., 2014), Peacox (Bothos et al., 2014), Quantified Traveler (Jariyasunant et al., 2015), Tripzoom (Poslad et al., 2015), Optimum (Anagnostopoulou et al., 2018), and SMART (Huang et al., 2018). The underpinning concept is based on the Fogg's framework (Fogg, 1998, 2003) in which system design is persuasive and explicitly attempts "to change attitudes or behaviors or both (without using coercion or deception)". This is achieved by raising awareness of individual choices, patterns, and the consequences of activities. Persuasive technologies, also termed as behavior change support systems

(BCSS), monitor human activities in relation to resource usage, and provide information to the user for the purpose of motivating behavioral change. Social motivators are also offered to influence the user's attitude and behavior. In general, persuasive technologies might have three functional roles including tool (i.e., increasing capability), social actor (i.e., creating relationship) and medium (i.e., providing experience). In the context of mobility, health and environmental feedback, tailoring travel options, self-monitoring, tunneling users toward green behavior, social networking, nudging and gamification elements are a number of persuasive features integrated to personal mobility-management tools (Brynjarsdottir et al., 2012). Although these new solutions may produce concerns regarding technology, privacy, reliability (Gadziński, 2018) and unintended externalities (te Brömmelstroet, 2014), empirical studies provide evidence that these new features are important in influencing users to change their travel behavior (Gabrielli and Maimone, 2013; Jariyasunant et al., 2015; Kazhamiakin et al., 2015; Poslad et al., 2015; Nakashima et al., 2017; Huang et al., 2018) .

The success of behavior change interventions highly depends on understanding the underlying mechanism and processes of behavior change, i.e., why and how behavior change occurs and what driving forces and determinants guide behavior. Michie et al. (2008) indicated that behavioral theories and models of behavioral change deliver a useful basis for designing effective interventions to change behavior. Likewise, the importance of a theoretical foundation to promote sustainable travel behavior is highlighted by McFadden (2007) since it allows for a "holistic understanding" of individual mobility behavior. Prior studies stressed the importance of a well-founded BCSS in behavioral theories since the foundation positively and significantly influences its effectiveness (Andersson et al., 2018; Arnott et al., 2014; Webb et al., 2010).

Tailoring the travel solutions that support individual needs and expectations can possibly lead to a powerful potential travel shift toward eco-friendly solutions. There is a wide agreement that satisfying user needs is fundamental for the design, implementation and dissemination of personal mobility-management tools aimed at encouraging VTBC (Gabrielli et al., 2014; Grotenhuis et al., 2007; Kramers, 2014; Meloni and Teulada, 2015; Wang et al., 2016). It is therefore necessary to understand the factors that influence the user acceptance, both drivers and barriers for their attraction and engagement, on the basis of behavioral theory. Nevertheless, as noted by Sunio and Schmöcker (2017) and Klein et al. (2014), there is a lack of research investigating "these new platforms for behavior change"(Fogg and Eckles, 2007) by the application of behavior theory. To the extent of our knowledge, there are only few research studies focusing on BCSS with support in behavioral theory e.g., Andersson et al. (2018), Pronello et al. (2017) and Jariyasunant et al. (2015). It still remains relatively unclear; thus more research is needed on this topic of ensuring the efficacy of this new generation of mobility-management tools (Kramers, 2014) for supporting sustainability-oriented decisions.

1.1. Aim and main contributions

The main purpose of this PhD project is to provide a better grasp of the motivators and barriers for advanced traveler information systems (ATIS) market penetration, which will aid authorities and private

entrepreneurs to design effective and appealing ATIS, eventually translating into wider potential of VBTC. The PhD project follows the stream of literature on investigating traveler's intention to use ATIS for daily trips, but extends previous research by filling the gap in current knowledge. It investigates the contributing factors to the use of a multi-faceted mobile app including both multimodal real-time traffic information and persuasive features. Most of the research regarding information technologies concerns their prospective impact and literature review revealed a lack of understanding about how individuals are motivated to accept and adopt such VBTC-based travel apps. Furthermore, there is a lack of sufficient attention to study of VTBC-based travel apps with support in behavioral theories. The main contribution of this PhD project lies in that it provides knowledge of critical facets when incorporating persuasive features with ICT for the purpose of sustainable mobility, through using behavioral theories, establishing theoretical framework and considering users perspective. This contributes to a better explanation of the user-sided heterogeneity, and accordingly to move away from the concept of "one size fits all" solution. The findings and analyses are based on four separate studies, presented in four chapters, centered around the main purpose of the project.

The first study (Participating in Environmental Loyalty Program with a Real-time Multimodal Travel App: User Needs, Environmental and Privacy Motivators, published in *Transportation Research Part D: Transport and Environment, 2018)* focuses on the underlying factors influence using the persuasive features of a mobility-management travel app. This is essential to understand the challenges related to attract users, and accordingly encourage behavior change in favor of sustainability. This study contributes to the body-of-knowledge by exploring Alderfer's (1969) ERG (Existence, Relatedness and Growth) theory as a motivator for the intentions to use the travel app. It investigates the influence of psychological aspects on the use intention by focusing on how well the integrated persuasive features contribute to the satisfaction of user needs. The study identifies functional and psychological user needs as backbone for user attraction and engagement. Furthermore, it explores the impact of barriers (e.g., information privacy concern) together with drivers (e.g. functional user needs) to provide a better explanation of users-sided heterogeneity observed in adoption behavior. Innovation resistance studies argue that it is even more important to comprehend innovation driven reasons against adoption. Previous research imply that ICT barriers can form negative attitude toward them which then can delay or impede the consumer adoption (e.g., Antioco and Kleijnen, 2010; Joachim et al., 2018). Previous literature confirmed that individual's engagement in actions might not only rest on weighing the expected costs and benefits, but on acting appropriately or morally (e.g., Czajkowski et al., 2014; Steg et al., 2014). Since the use of VBTC-based travel apps is likely to embrace aspects of personal morality and social responsibility, the study integrates environmental attitude in order to enhance the understanding of a wider set of motivators.

The second study (Use Intention of Mobility-Management Travel App: The Role of Users Goals, Technophile attitude and Community Resilience, Submitted to *Transportation Research Part A: Policy and Practice, 2018)* explores the underlying mechanisms of VTBC-based travel app users' behavior developed from Lindenberg's goal-framing theory (Lindenberg, 2006). This study investigates how

different motives (i.e., gain, hedonic and normative) guide the intention toward using the app depending on travel purpose. The behavioral framework also includes technophile attitude in order to analyze the relationship between technological affinity/aversion and adoption behavior. Previous behavioral research on ICT adoption showed that consumer's technophile attitude can be critical for the marketing of such technologies (Goulias et al., 2004; John, 2015). One of the main limitations of persuasive technologies is the exclusive focus on targeting specific behaviors and choices of individual citizens instead of proposing more collective approaches addressing the relevant communities that could have a higher impact on adoption. This approach contributes to neglecting the social dynamics outside the system condition and the need for changes at other scales beyond the individual users (Hekler et al., 2013; Strengers, 2011). The study addresses this issue by incorporating the notion of "Community Resilience", suggested by Leykin et al. (2013), to provide a better understanding of the social dynamic behind VTBC-based travel app.

The third study (Factors Driving the Adoption of Mobility-Management Travel App: A Bayesian Structural Equation Modelling Analysis, Accepted for *the Transportation Research Board (TRB), 98th Annual Meeting, Washington D.C., USA, January 13-17, 2019*) replicates the second study using the data from a different country (Portugal) in order to improve the current understanding of VTBC-based travel app adoption in a multicultural context owing to possible cultural differences in perceptions. Furthermore, the study provides insights to deal with the challenge of data analysis with small sample size.

The fourth study, a working paper, (Discovering Causal Structure from Observations: The Relationships between Technophile Attitude, Users Value and Use Intention of Mobility Management Travel App) investigates the applicability of causal discovery methods to evaluate behavioral framework established for the study of VTBC-based travel app adoption behavior. Compared to the conventional method in technology adoption research, this study adopts a reverse approach in which the relationships between theoretical constructs are explored by learning the causal structure from data.

1.2. Outline

The reminder of this dissertation includes the four papers, each within its own chapter. Finally, Chapter 6 concludes this dissertation by summarizing the main contributions from each of the four papers, policy implications and possible future paths for research.

2. Participating in Environmental Loyalty Program with a Real-time Multimodal Travel App: User Needs, Environmental and Privacy Motivators

Based on the accepted paper below:

Mehdizadeh, A., Kaplan, S., Silva, J. D. A. E., Nielsen, O. A. & Pereira, C. P (2019). Participating in environmental loyalty program with a real-time multimodal travel app: user needs, environmental and privacy motivators. *Transportation Research Part D: Transport and Environment, 67, 223-243*.

Presented at 57th ERSA Congress "Social Progress for Resilient Regions", 29 August-1 September 2017, Groningen, The Netherlands

ABSTRACT

The increasing complexity and demand of transport services strains transportation systems especially in urban areas with limited possibilities for building new infrastructure. The solution to this challenge requires changes of travel behavior. One of the proposed means to induce such change is multimodal travel apps. However, understanding the motivators underlying individuals' travel intentions is essential to design and evaluate their effectiveness. This paper pinpoints and analyses the drivers and barriers that influence individual travel decisions when using such apps. The analytical framework relies on Alderfer's ERG model of human needs that relate the individual's intentions to three domains, namely (1) Existence, (2) Relatedness and (3) Growth needs. Furthermore, environmental attitude, information privacy concerns and perceived difficulties when using the system are incorporated as to better explain user-sided heterogeneity. The case-study focuses on a new travel information system in Copenhagen (Denmark), which is not yet operational, through a technology-use preference survey among 828 travelers. Structural equation models revealed that the motivation for choices are specific to individual users and depend on wide-ranging factors that go beyond traditional economic and socio-demographic methods. The study revealed (1) different intentions among individuals according to the perceived value of the new information system, (2) a relation between different environmental attitude constructs and users' needs, (3) a stronger appeal to use the system for individuals with higher needs of developing social self-concept and eco-travel self-efficacy as well as with lower perceived privacy risk and perceived difficulties, (4) that both functional and psychological factors affect adoption intention.

Keywords: Travel app; Behavior change; Travel information; Persuasive technology; Need theory

2.1. Introduction

Transportation contributes 19% to global energy use and 23% to CO2 emissions related to energy consumption (IEA, 2014). Furthermore, urban mobility alone generates "40% of all CO2 emissions of road transport and up to 70% of other pollutants from transport" (EEA, 2017). Apart from the environmental issues, the continuous growth of mobility demand in modern cities increases traffic and affects the performance of transportation systems negatively. Given the current pattern of urban mobility, the environmental and transport-related issues will be aggravated, and therefore a concerted effort is needed to promote more sustainable mobility behavior and persuade individuals to change travel behavior in favor of environmentally friendly alternatives.

In order to promote sustainable mobility behavior, voluntary travel behavior change programs (VTBC) have been introduced aiming at nudging travelers toward sustainable modes of transportation. In this context, the use of advanced traveler information systems (ATIS) for improving mobility management in urban areas has received a lot of attention. ATIS have the potential to improve travel experience, enhance personal mobility and productivity of transportation since they allow travelers to make better informed travel decisions. ATIS assisted VTBC, such as ones tailored for and integrated in mobile applications, offer opportunities to raise travelers' awareness about their mode choices, travel pattern and the consequences of their mobility behavior such as travel time/energy saving, personal CO2 emission footprint, etc. These information technologies, besides their low-cost to decision makers and wide availability to the general public, are potentially powerful from the behavioral perspective. Problem awareness when giving information affects perceived responsibility, behavioral control and social norms. This, in turn, affects behavioral intentions and actions (Bamberg et al., 2011; Eriksson et al., 2006). Hence, VTBC-based information technologies are important tools in affecting travelers' decisions and guiding them toward sustainable travel behavior.

This paper describes a study of the intention to use a real-time multi-modal smartphone app aimed at motivating travel behavior change in the Greater Copenhagen Region (Denmark) toward promoting sustainable transport options. The prospective for mobility-management travel apps to stimulate sustainable mobility rests not only on the original and proper employment of the behavior change strategies, but also on "explicitly grounding it on established theoretical constructs from behavioral theories". The theoretical foundation is important because it positively and significantly influences the effectiveness of the system (Andersson et al., 2018; Arnott et al., 2014; Webb et al., 2010). However, a recent literature review by Sunio and Schmöcker (2017) revealed a lack of sufficient attention to explaining the users' behavior of mobility-management travel apps with support in behavioral theories.

This study focuses on exploring the motivation to use a new real-time multi-modal travel app for Copenhagen as ATIS for digital mobility-management assistance. The proposed app, which is not yet operational, integrates the elements suggested by Kramers (2014) for the next generation ATIS. The new VTBC-based travel app is a multi-faceted mobile app including both travel information and persuasive strategies such as health and environmental feedback, tailoring travel options, self-monitoring, tunneling users toward green behavior, social networking, nudging and gamification

elements. Due to the collaborative feature of this new generation of travel apps, a critical mass is essential for market penetration and use (see. Regulatory travel demand management policy measures are based on imposing travel costs or restrictions as external behavioral motivators. In contrast, the effectiveness of digital mobility management assistance as a voluntary tool for promoting sustainable transport is driven mostly by the user's need-based internal mechanisms of behavior. Meloni and Teulada (2015) describe three behavioral change elements that may induce target behavior through the use of ATIS: motivation, ability and triggers for behavioral change.

This study aims to explore these aspects through the lens of psychology and social science. In that, a better grasp of the motivators and barriers for ATIS market penetration will aid authorities and private entrepreneurs to design effective and appealing ATIS, eventually translating into a wider potential of VTBC, to reduce the transportation footprint in terms of air pollution and climate change and to enhance the quality of life through the reduction of commuting stress and promoting health through physical activity. The magnitude of the impact of ATIS on regions, cities and urban networks greatly depends on adoption diffusion and long-term engagement of users. Noticeably, this process is not distinctly technological, but has a social dimension that, forces a socio-technical evaluation, i.e. considering individuals' interaction with technology as well as other individuals in the process of study and design (Dickinson et al., 2015).

This study addresses the socio-technical perspective of ATIS adoption by offering to explore the underlying mechanisms of VTBC-based travel app users' behavior developed from Alderfer's (1969) Existence-Relatedness-Growth (ERG) theory of human needs. As they belong to commitment-oriented strategies, they are also more likely to be implemented because of their political acceptability (Gärling et al., 2004). They do not involve the ethical and normative issues that usually impede the public acceptance of pricing or monetary reward schemes (Di Ciommo et al., 2013; te Brömmelstroet, 2014). They encourage informed decisions, thus encouraging people to make a rational choice based on costs and benefits (Steg and Vlek, 2009), and make "the right choice for the right reasons" thus satisfying higher-order emotional needs of self-actualization that are important in long-term behavioral shifts (te Brömmelstroet, 2014). Further, tailor-made travel plans can alleviate contextual difficulties and induce temporary travel shifts so that people can reconsider their habitual behavior (Steg and Vlek, 2009).

The rest of the paper is structured as follows: Section 2.2 starts with literature review of VTBC- based travel information systems. Section 2.3 presents and discusses the motivational factors and barriers to adopt the new system and relevant literature review to support the proposed theoretical framework and corresponding hypotheses. Section 2.4 presents the mathematical method (i.e. Structural Equation Modelling) for testing the hypotheses. Section 2.5 and 2.6 introduces the case study, survey design, data collection as well as sample descriptions. Section 2.7 presents the results and discussions. Limitation and future direction is resented in Section 2.8 and finally, Section 2.9 concludes the paper.

2.2. Literature review

Most of the research regarding information technologies concerns their prospective impact. Chorus et al. (2006) and Ben-Elia and Avineri (2015) provide two comprehensive reviews regarding the potential of travel information to induce behavioral change and the behavioral mechanism of information acquisition and use. Chorus et al. (2006) provide insights on the magnitude of the effect, the contextual circumstances under which information use is effective, the impact of providing information on the chosen versus non-chosen alternatives, the type of travelers and trips that are more prone to information use, and the effect of information reliability and system familiarity. Ben-Elia and Avineri (2015) review the type of information used (i.e., descriptive, experiential, and prescriptive), the psychological heuristics that are related to information acquisition, and the effectiveness of information in changing travel behavior. In contrast, research on the effect of VTBC is scarcer. The rapid increase in information communication technologies (ICT) such as mobile phones and internet, has paved the way for promoting sustainable travel behavior through a better travel information provision (Ben-Elia and Shiftan, 2013). Taylor and Ampt (2003) reviewed the implementation of two mobility-management tools named Travel-Blending and IndiMark, applied in Adelaide, Brisbane and Perth, respectively. Large-scale field experiments proved that among participants, mobility-management tools are useful to significantly reduce car mileage, increase public transport ridership and to a lesser extent encourage cycling. Recent field experiments of a mobility-management program, the Quantified Traveler, shows similar prospects with respect to travel behavior change. The Quantified Traveler has a computer-based platform for travel diary collection and feedback; it still relies much on human assisted travel tailoring (i.e., Jariyasunant et al., 2015). The study by Mulley and Ma (2018) evaluated the long-term effects of a community based VTBC program, namely TravelSmart implemented in Adelaide, South Australia. Analyzing 3-year panel data collected by GPS tracking and survey method supported the effects of TravelSmart on reducing the amount of car driving in terms of both time and distance. Furthermore, the effects were found to be sustained over time. Froehlich et al. (2009) reveal that willingness to engage in eco-friendly travel is also independently sought regardless of VTBC programs, even in the U.S., a highly car-oriented country. In their survey, 13% of the respondents combined travel with exercise, 61% had taken at least one action with a direct goal of eco-friendly travel, including reducing car travel, using more fuel efficient cars, trip chaining and walking. Hence, VTBC address a potentially larger market demand for travel behavior change.

Traditional VTBC solutions require person-based interaction, either by phone or home interviews, which is inherently expensive and may induce biases stemming from social interaction and communication. ATIS assisted VTBC offers opportunities to reduce the costs associated with the need for human-based interaction. While most travel apps are still based on the traditional view of digitized traffic information, the newest generation of ATIS includes user-based alerts, prescriptive advices (e.g., route alternatives and changes), reflective memory (e.g., the ability to save past and future trips and locations), and persuasive strategies (i.e., carbon emission scores, interaction with social networks, and loyalty points that can be redeemed for rewards) (see e.g., Brazil et al., 2013; Brazil and Caulfield, 2013; Wilhelms et al., 2017; Yujuico, 2015). Replacing human interaction with ATIS digital schemes are currently under

development offering, among other things, opportunities for communication and collaboration across users, information sharing and social networking (e.g., Ferreira et al., 2017; Kramers, 2014; Meloni and Teulada, 2015; Pronello et al., 2016). Although these new solutions may produce concerns regarding technology, privacy, reliability (Gadziński, 2018) and unintended externalities (te Brömmelstroet, 2014), field experiments provide evidence that these new features are important in influencing users to change their travel behavior in favor of green or sustainable travel (Andersson et al., 2018; Castellanos, 2016; Coombes and Jones, 2016; Khoo and Asitha, 2016; Nakashima et al., 2017; Poslad et al., 2015).

Andersson et al. (2018) performed a literature review on how smartphone applications are effective in supporting behavior change in the domains of energy and climate, health and transport. The results suggest that user customization, relevant and contextualized information and feedback, commitment, and appealing design are significant facets to encourage behavior change. Castellanos (2016) investigated the effects of financial incentives delivered through mobile phones to promote modal shift toward environmentally friendly modes of transportation. The results of the field study showed that users' extrinsic and intrinsic motivation for behavioral change, as well as tailoring mobile applications that support individual needs and expectations, are important to modify traveler behavior. Coombes and Jones (2016) explored the use of a tracking technology with a reward scheme, "Beat the Street", for encouraging active travel in children through a quasi-experimental study. They found that gamification could increase engagement and possibly promote active travel modes in the short term. However, its long term effect to change and maintain the desired behavior is an important issue for information communication technologies (ICT). Through a stated preference survey, Khoo and Asitha (2016) showed that real time traffic information is one of the most required features of smart phone traffic information apps which furthers their adoption. They found that individual preferences regarding the app features are very important with a view to developing more efficient transport practices since it enables an increase in the users' compliance with the delivered information (e.g. diverting to alternative routes). Nakashima et al. (2017) investigated the effect of a smartphone app with the function of gamification including scoring, ranking and competition in changing travel behavior (i.e. increasing number of steps) through a before-after study design. The results revealed that the effectiveness of the developed app in changing behavior depends on users' current walking behavior as well as their personality. More specifically, this is effective for people who do not usually walk too much and particularly for people who have a competitive personality. Poslad et al. (2015) studied the impact of different travel incentives (i.e. traveler mobility pattern, targets and challenges, loyalty points and social networks) through the use of the Tripzoom app on motivating users to embrace sustainable mobility in the cities of Enschede, Gothenburg and Leeds for a period of six months. The main findings support the effectiveness of the incentives to encourage travel behavior change. However, providing users with customized information, feedback and goals aligned with their specific needs were found essential to trigger behavior change. Additionally, an appealing and simple design appeared to be important to the users.

2.3. Theoretical framework

Tailoring the travel solutions to support individual needs and expectations can possibly lead to a powerful potential travel shift toward eco-friendly solutions. There is wide agreement that satisfying user needs is fundamental for the design, implementation and dissemination of mobility-management travel apps aimed at encouraging VTBC (Andersson et al., 2018; Gabrielli et al., 2014; Grotenhuis et al., 2007; Meloni and Teulada, 2015; Wang et al., 2016). This study contributes to the body-of-knowledge by exploring Alderfer's (1969) ERG (Existence, Relatedness and Growth) theory as a motivator for the intentions to use mobility-management travel apps. The ERG theory, which evolved from Maslow (1943)'s theory of human motivation and received greater empirical support, is based on a threefold conceptualization of human needs: (i) Existence (i.e., functional needs), (ii) Relatedness (i.e., belonging, togetherness), and (iii) Growth (i.e., self-esteem, self-actualization). While the concept of needs is long-standing in empirical psychology for studying motivation, with the shift toward cognitive theories this concept was largely replaced by goal-related efficacy formulated as functional utility (Deci and Ryan, 2000).

The self-determination theory (SDT) revisits the need-based approach due to the understanding that intrinsic motivation to satisfy higher-order emotional needs of relatedness and growth (i.e., autonomy and competence) is an important part of goal-directed behavior (Deci and Ryan, 2000). Because the SDT largely focuses only on satisfying emotional needs as intrinsic motivation for goal-directed behavior, the current study extends the SDT model to represent functional, relatedness and growth needs. Andersson et al. (2018) used a theoretical framework including the Theory of planned Behavior (TPB), the Transtheoretical Model (TTM), Diffusion of Innovations (DI), and the concept of Gamification for explaining important factors in constructing a behavior change support system (BCSS) for smartphone applications. This study follows the same line of research as Pronello et al. (2017) who investigated the intentions to use the "Optimod'Lyon" multi-modal travel app by applying the TPB. The two theories, the TPB and the ERG theory of needs are linked through the notion of decision factors originating from personal identity and situational concerns. Personal identity could be studied using the theory of human needs, where the satisfaction of needs motivates individuals to engage in action (Woodbine and Liu, 2010) and the two theories can also be viewed as complementary (Gucciardi and Jackson, 2015). While simple navigation apps are mostly driven by their functional value, the general mobile app use and adoption is driven by a wide range of psychological needs: functional, social, self-esteem and self-actualization needs (Kim and Baek, 2018; Sun et al., 2017). Hence, as recommended by Dickinson et al. (2015) this study identifies functional and psychological user needs as backbone for user attraction and engagement.

The widely used theories in innovation adoption behavior such as the TAM and TPB focus more on individuals' perceived drivers to use innovations while the factors leading to consumer resistance are disregarded. Innovation resistance studies argue that it is even more important to comprehend innovation driven reasons against adoption. Previous research implies that innovation barriers can form negative attitudes toward them which can then delay or impede consumer adoption (Antioco and

Kleijnen, 2010; Joachim et al., 2018; Kleijnen et al., 2009; Laukkanen et al., 2008). Moreover, a recent study shows that the influence of barriers on adoption intention is almost twice as strong as those of adoption factors (Claudy et al., 2015), underscoring the necessity of addressing the barrier effects.

As proposed by Ram and Sheth (1989), the barriers could be categorized into functional and psychological. Two of them are the usage barrier and the risk barrier that we investigate in this study. The usage barrier is associated with perceived usefulness or ease of use while the risk barrier is related to perceived risk. In the context of VTBC-based travel app adoption, the usage barrier may be relevant to the issues of e.g. complexity of the idea and use, time-consuming, and unsatisfied expectations about the gamification elements (i.e. incentives and rewards). The risk barrier for instance relates to the privacy and security concerns of the app users for online activities. With ICT advancement, concerns about data privacy and its impacts have arisen. The concerns mainly related to improper information collection, storage, protection from disclosure to unauthorized persons and use the information for unintended purposes without their permission (Hong and Thong, 2013). This has motivated researchers to investigate extensively the information privacy in online environmet. In the context of E-commerce, there is wide agreement that information privacy concerns influence individuals' attitude toward online services and acceptance (e.g., Bergström, 2015; Fortes and Rita, 2016; Kim et al., 2011). Previous literature has examined users' perceived concerns of leaking of personal information when they share their activities on social media (Chang and Heo, 2014; Christofides et al., 2009; Fortes and Rita, 2016; Lemay et al., 2017; Taddicken, 2014; Waters and Ackerman, 2011). Little connection was found between the intention of self-disclosure and the concern of privacy invasion (Christofides et al., 2009; Lemay et al., 2017). People ignore privacy risks when exhibiting their activities on social media, particularly when they trust them (Waters and Ackerman, 2011), since they are under the impression that such information is only accessible within the network that they developed (Taddicken, 2014). When it comes to mobile applications, however, the negative effect of privacy concerns on download and use intention was reported by prior literature (e.g., Gu et al., 2017; Shklovski et al., 2014). Our study investigates the barrier effects as reasons against adoption of VTBC-based travel apps along with the reasons for their adoption, captured by functional and emotional perceived benefits. As the barriers represent perceived behavioral control, they supplement the ERG theory.

Individual's engagement in actions may not only rest on weighing the expected costs and benefits but the desire to act appropriately or morally. Therefore, moral and normative considerations also guide individual behavior and action. People may engage in environmental conservation or preservation activities due to the benefits to others or the environment, instead of appealing to self-interest even if these actions involve some costs and efforts (Czajkowski et al., 2014; Steg et al., 2014). In the context of mobility, various studies supported that environmental attitude and concern exert some influences on travel behavior. Nilsson and Küller (2000) showed that environmental attitudes are positively associated with people's willingness to reduce car usage or to support car travel reduction measures. Vredin Johansson et al. (2006) found that attitudes toward being pro-environmentally inclined influence the choice of an environmentally friendly mode (i.e. train) over a less environmentally friendly mode (i.e.

bus). Clark et al. (2016) presented that willingness for environmental protection precedes a change in travel behavior toward non-car and active commuting. Kim et al. (2017) found that people's intention to use a shared car is significantly influenced by a pro-environmental attitude. Bouscasse et al. (2018) showed that people with high environmental concern have favorable attitudes toward the use of public transport (i.e. easy, useful and pleasurable) compared to those who do not have such environmental motivation. Furthermore, environmental concern influences public transport habits positively and car use habits negatively.

Since the use of VTBC-based travel apps is likely to embrace the aspects of social responsibility and personal morality, our study also integrates environmental attitude in order to enhance our understanding of a wider set of motivators governing the user attraction and engagement. As suggested by Ajzen and Fishbein (1980) as well as Bamberg (2003), environmental attitude as a general attitude does not have a direct effect on specific behaviors, but it is indirectly determinant through situation-specific beliefs and attitude. Hence, our study investigates the effect of environmental attitude on individual intention to use a VTBC-based travel app mediated by its perceived values. Figure 2-1 describes the conceptual behavioral framework. Based on the above literature support, the hypothesis related to the model in this study is proposed as follows:

H1: Satisfying functional and psychological user needs relates positively to adoption intention
H2: Stronger perceived usage difficulties relates negatively to adoption intention
H3: Stronger information privacy concern relates negatively to adoption intention
H4: Environmental attitude has an effect on adoption intention, mediated by user's functional and psychological needs

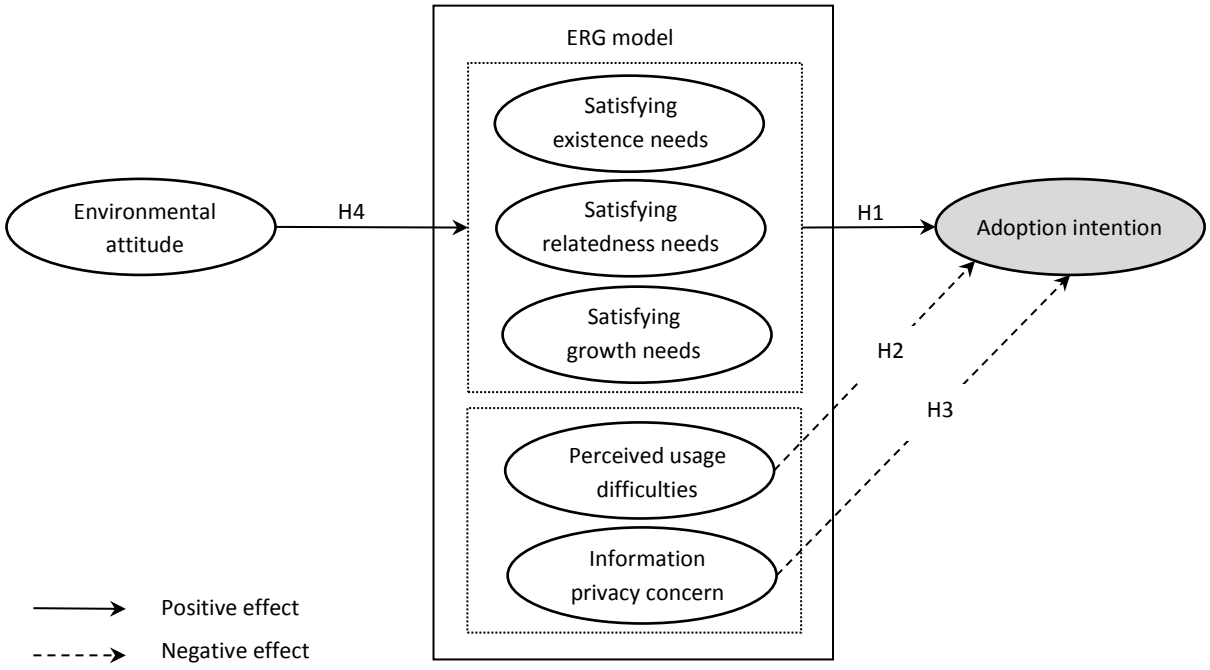


Figure 2-1 Conceptual model on motivations to use the app

2.4. Behavioral model

The behavioral model structure representing the research hypotheses was investigated by applying structural equation modeling (SEM). SEM is a confirmatory analysis technique that tests models that are conceptually derived beforehand and evaluates how well the theory fits the collected data (Hair et al., 2006). The SEM foundation lies in two multivariate techniques: confirmatory factor analysis (CFA) and multiple regressions, also called path analysis, which test measurement and structural equations simultaneously. The measurement equations represent relations between latent constructs and their respective indicators while structural equations represent the directional relations between latent constructs. The methodology is comprehensively described by Pugesek et al. (2003). An increasing number of recent studies employed SEM to examine the use of travel mobile apps (Assemi et al., 2018; Fang et al., 2017; Im and Hancer, 2017; Lu et al., 2015; No and Kim, 2014; Weng et al., 2017).

In this study, the model is constructed by four equations that we explain below.

$$I_{rn} = Z_{ln}^{*}\,\alpha_r + \upsilon_{rn} \quad \text{and} \quad \upsilon_{rn} \sim N(0, \Sigma_{\upsilon}) \quad \text{for} \quad r = 1, \dots, R \tag{1}$$

$$Z_{ln}^{*} = X_{ln}\beta_l + \omega_{ln} \quad \text{and} \quad \omega_{ln} \sim N(0, \Sigma_{\omega}) \quad \text{for} \quad l = 1, \dots, L \tag{2}$$

$$Z_{l}^{*} = Z_i\beta_i + \varphi_l \quad \text{and} \quad \varphi_l \sim N\left(0, \Sigma_{\varphi}\right) \quad \text{for} \quad l = 1, \dots, L \;\&\; i = 1, \dots, K \tag{3}$$

$$Y_n = Z_{ln}^{*}\gamma_Z + \xi_n \quad \text{and} \quad \xi_n \sim N\left(0, {\sigma_{\xi}}^2\right) \tag{4}$$

Where Eq. (1) links the measurement indicators (i.e. questionnaire items) to the latent constructs. I_{rn} refers to the value of an indicator *r* related to latent construct Z_{ln}^{*} as perceived by respondent *n.* The value of latent construct *l* for respondent *n* is labeled with Z_{ln}^{*} and α_r is the corresponding factor loading. The error term is expressed as element υ_{rn} which is a vector following a normal distribution with covariance matrix Σ_{υ}. Eq. (2) links the latent constructs Z_{ln}^{*} to individual characteristics. X_{ln} is a vector of the respondents' individual characteristics (e.g. socio-economic and travel habit) and β_l are the parameters representing the regression relations. The error term is ω_{ln} which is a vector following a normal distribution with covariance matrix Σ_{ω}. Eq. (3) relates the explanatory latent constructs Z_i (e.g., environmental attitude) with the mediator latent constructs Z_l^{*} (e.g. the three groups of needs) through parameters β_i. The error term is φ_l following a normal distribution with covariance matrix Σ_{φ}. Eq. (4) represents regression relations between the latent constructs Z_{ln}^{*} and the target variable Y_n through parameters γ_Z. Here, Y_n is the likelihood levels of using the app by respondent *n* (i.e. in 1-5 Likert scale from highly unlikely to highly likely). The error terms is presented as ξ_n.

The commercial software M-Plus was used to estimate the parameters of the model (Muthén and Muthén, 2012). The parameters of the four sets of equations were estimated simultaneously by using Maximum Likelihood with Huber-White covariance adjustment (Yuan and Bentler, 2000). Standard errors were computed using the White's sandwich estimator which provides robust statistics to the non-normality of the indicators as well as the categorical variables (White, 1980). The goodness-of-fit was measured using three different indices including the Comparable Fit Index (CFI) (Hu and Bentler, 1999),

the Root Mean Square Error of Approximation (RMSEA) (Browne and Cudeck, 1992) and the Standardized Root Mean Square Residuals (SRMR) (Bollen, 1989). CFI index compares the estimated model with an independent, or null, model. RMSEA index specifies to what extent the observed covariance matrix and the hypothesized covariance model are different. SRMR is an index of the average of standardized residuals between the sample covariance matrix and the hypothesized covariance model. A cut-off value for CFI greater than or equal to 0.90 and RMSEA smaller than 0.05 represent good fit. A RMSEA value falling between the range of 0.05 and 0.08 is the indicator of accepted fit. A SRMR value smaller than 0.05 is the indicator of good fit while a value between 0.05 and 0.08 indicates accepted fit (Hu and Bentler, 1999; Kline, 2011).

2.5. Case study

A new advanced real-time multimodal travel app is under investigation for Copenhagen traffic management enhancement. The idea behind the system is to integrate traffic information and journey planning to include all modes of transport. It includes multi-modal real-time information, multi-criteria route planning on the basis of time and cost, multi-modal choice combinations, ridesharing opportunities and easy payment. In order to induce behavioral change, persuasive strategies are also considered by the system designers. For more information, see PPI ITS Project, (2014). Persuasive Technology (Fogg, 1998, 2003), which is an inspiration for more researchers in this field, has focused on system design explicitly attempting “to change attitudes or behaviors or both (without using coercion or deception)”. This is achieved by raising awareness of individual choices, patterns, and the consequences of activities. The persuasive technologies monitor human activities in relation to resource usage, and provide information to the user for the purpose of motivating behavioral change (Brynjarsdottir et al., 2012). Challenges & goal setting, self-monitoring, social networking & comparison, gamification and rewards are among the main strategies adapted to design persuasive technologies.

The new travel app is supposed to provide the users with information about CO2 emissions produced/saved by taking different travel options and the amount of calories burnt by taking active modes. It is also possible to monitor CO2 savings and calorie consumption over time. Moreover, the app enables its users to register for an environmental-friendly loyalty program: the more an environmental-friendly itinerary they take, the more bonus points they earn. The bonus points can be used to get some free services (through vouchers) or public transport tickets. The collected bonus points and travel information, i.e. CO2 emissions saved and calories burnt, could be shared on social media. On the level of design, therefore, the travel app has been considered to consist of health and environmental feedback, tailoring travel options, self-monitoring, tunneling users toward green behavior, social networking, nudging and gamification elements. In this respect it is fairly similar to other mobile apps currently under development: Ubigreen, MatkaHupi, Peacox, SuperHub, Tripzoom and IPET (Meloni and Teulada, 2015). However, as a hypothetical scenario in this study, the persuasive features of the app are only accessible, if the users create a personal account; hereafter “GREEN account”, provides the system with some personal information, and allows the system to record their travel behavior. Without having “GREEN account” activated, the app serves as a typical travel app. It is important to note that, the

GREEN option, in this format, is not part of the initial app design. We formulated the “GREEN account” in order to investigate the users’ behavior regarding the persuasive features in a more appropriate manner and accordingly, address the research objectives.

2.6. Method and materials

A tailor-made web-based questionnaire was designed according to the developed behavioral framework. At the beginning of the questionnaire, participants were supported with information related to the functionalities and features of the new travel app such as multimodal travel information, incorporated persuasive strategies, the need for creating “GREEN account” to access the persuasive attributes, the policy of monitoring their travel behavior etc. The survey elicited the following information; (1) the likelihood of using the app through “GREEN account” measured on a 5-point Likert scale ranging from highly unlikely to highly likely (2) a set of user motivations to use the app to estimate the constructs in relation to the ERG model (3) perceived barriers to use the app in terms of usage difficulties and information privacy concern (4) environmental attitude and (5) a set of background variables such as age, gender, income, travel habit, family status etc.

With respect to the ERG model, respondents were asked the question, “How can registration for the “GREEN account” satisfy your travel needs for the daily commute?”. The statements of the three dimensions of the ERG model were measured using the 5-point Likert scale ranging from strongly disagree to strongly agree.

Existence needs incorporated items related to increasing travel efficiency such as travel time and monetary savings when using travel information. Travel time and cost savings were defined as functional needs based on previous studies presenting trip efficiency as the most desired feature for the users of travel information (Chorus et al., 2007; Grotenhuis et al., 2007). Furthermore, in a literature based study, Vogelsang et al. (2015) proposed a framework for integrating the needs of travelers and app users and identified travel time and cost savings amongst the main factors that guide the use of travel information.

Relatedness needs explored items regarding travel information sharing and its value for users to form or maintain interpersonal relationships and satisfy a sense of belonging. In the field of social psychology, sociology and marketing, theories and research argue that products have social value, which may guide product purchase and use, e.g. theory on the extended self (Belk, 1988), theory on the meaning of material possessions (Dittmar, 1993), theory on brand concept management (Park et al., 1986) and self-congruity theory (Sirgy, 1986). Social value reflects the (positive or negative) outcomes of the ownership and use of a product for one’s (self-) identity and social status. It is viewed as the product’s ability for developing social self-concept.

Growth needs investigated items related to developing environmental self-identity (e.g. adopting a more environmentally-friendly travel behavior and contributing to sustainable development of the city)

as well as self-concept associated with self-confidence and self-efficacy to embark on travel behavior changes.

The perceived barriers for using the app were expressed as perceived usage difficulties (e.g. ease of use, mental relaxation and relative advantages related to the offered incentives) and perceived risk when it comes to information provision online. We employed the conceptualization of information privacy concern inventory developed by Hong and Thong (2013) in an online context. In our study, the model included the four dimensions of "Information collection", "Secondary usage", "Improper access" and "Trusting beliefs". Information collection refers to "the degree to which a person is concerned about the amount of individual specific data possessed". Secondary usage is "the degree to which a person is concerned that personal information is collected for one purpose but is used for another, secondary purpose without authorization from the individual". Improper access refers to "the degree to which a person is concerned that personal information is readily available to people not properly authorized to view or work with the data". Trusting beliefs refer to "the degree to which people believe a service provider is dependable in protecting personal information". The conceptual framework of information privacy concern is presented in Figure 2-2. The information privacy concern is the second order factor measured by those four first-order factors. The statements of perceived barriers were measured using the 5-point Likert scale ranging from strongly disagree to strongly agree.

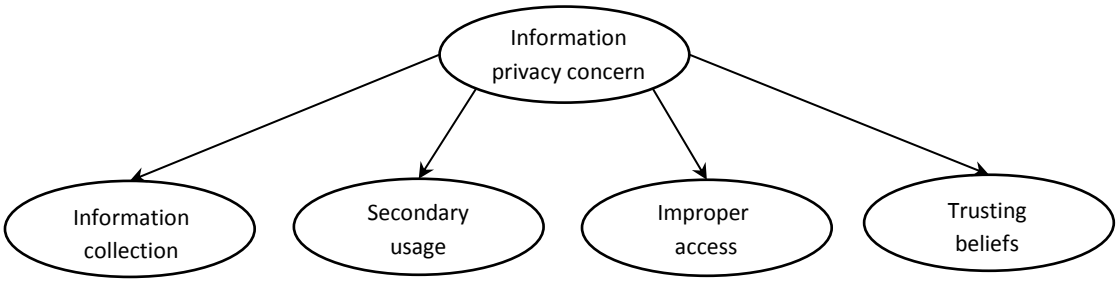


Figure 2-2 Conceptual model on information privacy concern

We assess environmental attitudes with the Environmental Attitude Inventory (EAI) developed by Milfont and Duckitt (2010) after shortening and adapting it to the context of online travel information provision. The environmental attitude incorporated the four dimensions of personal conservation behavior (i.e. taking care of resources and environmental protection in personal daily behavior such as energy saving and recycling), trust in travel information technology (i.e. belief in the ability of the information technology to alleviate traffic issues and promote environmental friendly travel behavior), human impact on environment (i.e. belief in negative environmental consequences of economic progress and a need for adopting more serious action) and environmental movement activism (i.e. personal interest and desire to support or participate in organized actions related to environmental issues).

Individual characteristic comprised socio-economic variables and travel habits. The travel habits comprised frequency of traveling by car, public transport and bicycle as well as the frequency of commuting alone, with others (i.e. necessarily adults) and with children. The frequency was measured

on a 5-point Likert scale including never/rarely, less than 3 days a month, once a week, 2-3 days a week and daily. The respondents were also asked to give information about the membership cards they held, since we wanted to test whether there is a relationship between the number of memberships held by each individual and the degree of online privacy concern. The question included multiple choices of supermarket/shopping club cards, fitness club, car/bike sharing, housing association and labor union.

The survey was administered in Danish from mid-May to mid-June 2017 to a sample of commuters who were older than 18 and resided or worked in the greater Copenhagen area. Technical University of Denmark (DTU), Copenhagen municipality and a number of companies were selected. As for the individuals who either worked or studied at the university, the email addresses were accessible, and they were therefore contacted directly. The questionnaire was distributed amongst the companies registered in the list of the Danish Bureau of Statistics. Companies with more than ten employees located in the region were included. For the sake of recruitment, more than 5000 email invitations were sent. Copenhagen municipality also posted the questionnaire on their portal for distributing to its employees which allowed obtaining a larger sample size.

The survey yielded 828 fully completed responses. It is considered as an adequate sample size based on a rule of thumb of requiring ten responses for each of the 39 indicators designed for our study (Nunnally et al., 1967). Table 2-A shows the sample characteristics compared to the data from the Danish National Travel Survey (TU) presented in brackets. The TU data used included only the greater Copenhagen area from 2015 to 2017 and adult people who commuted either by passenger car or public transport or active modes.

Variable	Categories				
Gender	Male	Female			
	50% (49%)	50% (51%)			
Age	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age>60
	33% (23%)	21% (21%)	19% (20%)	18% (16%)	10% (21%)
Employment	Student	Part time	Full time	Other	
	22% (12%)	4% (11%)	69% (54%)	5% (23%)	
Family status	Single no children	Couple no children	Single with children	Couple with children	
	19% (30%)	45% (31%)	4% (5%)	31% (34%)	
Commute distance	0-5 km	6-10 km	11-20 km	21-30 km	> 30 km
	19% (39%)	24% (17%)	28% (11%)	12% (4%)	17% (29%)
Annual income before tax (DKK)	Under 200,000	200,000 – 400,000	400,000 – 500,000	500,000 – 750,000	Over 750,000
	22% (28%)	29% (37%)	22% (16%)	20% (14%)	8% (6%)
Income groups in this study	Low	Medium	High medium	High	High
Number of membership cards *	No membership	1	2	3	More than 4
	12%	29%	35%	19%	4%
** Since this data, in this format, is not available in TU, they were not compared.*					

Table 2-A Sample characteristics, Total sample size = 828

The sample characteristics are in line with the survey aim and scope to target adult commuters in the Greater Copenhagen Area. The sample is gender-balanced which agrees with the TU data, and mostly

includes adults who are students or full-time employees. Our sample is considerably different from the TU data in many categories, which was anticipated due to the choice of recruitment. For example, almost one fourth of the participants were students. They are typically young and, therefore in our sample the share of age group (18-29) is higher than in the TU data. Correspondingly, it influenced other categories as well. Another reason can be related to the recruitment of employees through companies not directly.

2.7. Results

2.7.1. Factor analysis

All the constructs of the behavioral framework including ERG needs, perceived usage difficulties, information privacy concern, and environmental attitude were obtained by exploratory factor analysis (EFA). EFA was employed to expose the underlying structure of the variables and investigate the theoretical constructs.

From a preliminary descriptive statistics analysis on the survey data, we observed good internal consistency with Cronbach's alpha 0.80 and good sampling adequacy with Kaiser-Meyer-Olkin (KMO) = 0.87. The determinant of the Spearman correlations matrix equal to 7.2E-9 also indicates absence of multi-collinearity, and the Bartlett's test for sphericity rejected the null hypothesis of an identity correlation matrix. Principal axis factoring (PAF) with orthogonal "Varimax" rotation generated the three factors of the ERG needs, the five factors of the perceived barriers, and the four factors of environmental attitude. Both the scree plot and parallel analysis implemented in R package "psych" (Revelle, 2016) suggest the same number of factors (refer to Appendix A for details). Regarding the generated factors, Tables 2-B through 2-D below show the loadings of the dominant items and their descriptions. The cut off of 0.5 was set to retain a set of items representing the factors. The Cronbach's alpha of each factor is also presented in brackets. Most of the Cronbach's alpha values are above 0.7 reflecting good internal consistency (Miller, 1995), except for F4 and F11 that are just acceptable since they are above the "criterion-in-use" of 0.6 (Peterson, 1994).

As shown in Table 2-B, factors F1, F2 and F3 are related to the satisfaction of personal needs. Factor F1, "Trip-efficiency improvement", includes two items of satisfying basic travel needs in terms of saving travel time and cost by using the app. Factor F2, "Social self-concept development", is about the social attributes of the app to satisfy relatedness needs. It incorporates all statements about social interaction, sharing information, helping others and gaining social approval. Factor F3, "Eco-travel promotion", is associated with the value of using the app to satisfy higher order needs of self-efficacy (e.g. changing travel behavior for the sake of one's own health, the city or the environment) and develop an environmental self-identity. In Table 2-C, factor F4, "Perceived usage difficulties", includes the personal perceptions of the app being generally unappealing, stressful and unattractive in terms of the offered incentives. Factors F4, F5, F6 and F7 are about the four dimensions of information privacy concern, of which the first three include the perceived risks and the last one the perceived trust of online information provision. As shown in Table 2-D, factors F9, F10, F11 and F12 include the four dimensions of environmental attitude as explained previously.

Based on the "two-indicator rule" characterized by (Bollen, 1989), the model is identified with at least two indicators per factor if the model has two or more factors. Particularly as our sample size is not small, the model is not susceptible to estimation problems (Kline, 2011).

It is worth mentioning that the factor structure extracted by the EFA was then used to perform the SEM model. The aim of the EFA was to identify underlying constructs for a set of measured variables in the absence of a priori hypotheses, whereas the aim of the CFA was to test how well the data fit a hypothesized, a priori, measurement model. When it comes to our data set, the factor structure is initially revealed by EFA and then used as part of the model structure with CFA, which improves the structural validity of the proposed model.

Factor name (Cronbach α)	Acronym	Item	Factor loadings
F1 (0.82)	TE1	It would save me travel time	0.77
Trip efficiency improvement	TE2	It would make my trip cheaper	0.77
F2 (0.85)	SS1	Sharing my CO2 savings and burnt calories on my social media could be fun	0.83
Social self-concept development	SS2	I could enlarge my social network with sharing my trip information	0.83
	SS3	I would feel part of the community	0.54
	SS4	I could help others by sharing my CO2 savings on social media	0.74
F3 (0.88)	EP1	It would help me make healthier travel choices	0.76
Eco-travel promotion	EP2	It would help me make greener travel choices	0.84
	EP3	I could contribute to the city vision for CO2 level reduction	0.64
	EP4	"GREEN account" would make my trip more environmentally friendly	0.75
Cronbach's alpha=0.88, KMO = 0.85, Determinant of the Spearman correlations matrix= 0.0043			

Table 2-B Rotated factor matrix for the ERG needs

Factor name (Cronbach α)	Acronym	Item	Factor loadings
F4 (0.64)	UD1	I would not like to run the app while travelling	0.51
Perceived usage difficulties	UD2	Trying to earn eco-points could be stressful	0.50
	UD3	The offered incentives do NOT answer my needs	0.54
	UD4	"GREEN account" is too time consuming compared to the offered benefits	0.61
F5 (0.78)	IC1	It bothers me when they ask me for personal information	0.72
Information collection	IC2	I think twice about providing my personal information	0.55
	IC3	I am concerned they collect too much information about me	0.75
F6 (0.88)	SU1	My personal information could be used for other purposes	0.49
Secondary usage	SU2	Providers could sell my personal information to third parties	0.82
	SU3	Providers could share my personal information without my authorization	0.52
F7 (0.88)	IA1	The databases are not protected from unauthorized access	0.82
Improper access	IA2	Providers generally do not devote enough effort for preventing unauthorized access	0.80
	IA3	Websites can be hacked and leak personal information to the public	0.75
F8 (0.88)	TB1	They will keep my best interests in mind when dealing with my personal info	0.78
Trusting beliefs	TB2	They fulfill their promises related to my personal information	0.86
	TB3	They are predictable/reliable for the usage of my personal info	0.83
Cronbach's alpha= 0.75,KMO = 0.88, Determinant of the Spearman correlations matrix= 0.0003			

Table 2-C Rotated factor matrix for the perceived barriers constructs

Factor name (Cronbach α)	Acronym	Item	Factor loadings
F9 (0.78)	HI1	If things continue on their present course, we will soon experience a major env. crisis	0.63
Human impact on	HI2	People have been giving little attention to how economic progress damaging the env.	0.75
environment	HI3	The negative env.* effects of economic growth should be considered by politicians	0.77
F10 (0.76)	TT1	Better travel information helps to reduce traffic congestion	0.71
Trust in travel Info	TT2	The internet technology reduces people's daily travel	0.73
technology	TT3	Better travel information is useful to travel in a greener way	0.69
F11 (0.65)	PC1	At home, I control the heating system so the temp is not too high	0.49
Personal	PC2	I always turn off the light when I leave the room	0.57
conservation	PC3	I save water as much as I can	0.77
behavior	PC4	I recycle waste as much as I can	0.50
F12 (0.75)	EM1	I believe that social and environmental campaigns make a difference	0.59
Environmental	EM2	I am prepared to help out in environmental campaigns	0.71
movement activism	EM3	I sign petitions or donate money to support an environmental issue	0.66

Cronbach's alpha=0.78, KMO = 0.80, Determinant of the Spearman correlations matrix=0.0029
** env. stands for environment/environmental*

Table 2-D Rotated factor matrix for the environmental attitude

2.7.2. Model estimation results

The Shapiro-Wilks test for univariate normality (Shapiro and Wilk, 1965), as well as the Mardia's test for multivariate normality (Mardia, 1970), shown in Appendix 2.B, rejected the null hypothesis that the sample comes from a multivariate normal distribution. Thus, Maximum Likelihood with Huber-White covariance adjustment was employed to estimate the model parameters (Yuan and Bentler, 2000).

The model comprising both structural and measurement equations fits the data reasonably well. The scaling correction factor, the standard chi-square divided by the scaled chi-square, is 1.059 indicating that the non-normality is not problematic, i.e. the chi-square inflation is less than 10% (Newsom, 2005). The chi-square to degrees of freedom ratio is 2.17 (χ^2 = 3059.728, df = 1407), which is indicative of an "acceptable" data-model fit (Schermelleh-Engel et al., 2003). The tested model revealed a goodness-of-fit measure in terms of RMSEA equal to 0.038. The SRMR is 0.071 within the acceptable range of 0.05-0.08 (Hu and Bentler, 1999). The CFI is 0.890, which is also acceptable as suggested by Loehlin (1998). Tables 2-E through 2-H show the standardized parameters estimates, critical ratios (C.R.), defined as the ratio of parameter estimate and standard error, as well as p-values.

Table 2-E presents the estimates of the measurement equations of the CFA that agrees with the EFA displayed in Tables 2-B, 2-C and 2-D.

Factor name	Item	*est.*	*C.R.*	*p-value*
Trip efficiency	It would save me travel time	1.000	-	-
Improvement (F1)	It would make my trip cheaper	1.086	17.847	<0.001
Social self-concept	Sharing my CO2 savings and burnt calories on my social media could be fun	1.000	-	-
development (F2)	I could enlarge my social network with sharing my trip information	0.858	28.786	<0.001
	I would feel part of the community	0.684	10.528	<0.001
	I could help others by sharing my CO2 savings on social media	0.872	15.033	<0.001
Eco-travel	It would help me make healthier travel choices	1.000	-	
promotion (F3)	It would help me make greener travel choices	1.071	45.048	<0.001
	I could contribute to the city vision for CO2 level reduction	0.677	19.054	<0.001
	"GREEN account" would make my trip more environmentally friendly	0.925	28.495	<0.001
Perceived usage	I would not like to run the app while travelling	1.000	-	-
difficulties (F4)	Trying to earn eco-points could be stressful	1.008	8.110	<0.001
	The offered incentives do NOT answer my needs	1.214	8.476	<0.001
	"GREEN account" is too time consuming compared to the offered benefits	1.022	9.281	<0.001
Information	It bothers me when they ask me for personal information	1.000	-	-
collection (F5)	I think twice about providing my personal information	0.542	13.451	<0.001
	I am concerned they collect too much information about me	1.038	25.466	<0.001
Secondary usage	My personal information could be used for other purposes	1.000	-	-
(F6)	Providers could sell my personal information to third parties	1.172	29.454	<0.001
	Providers could share my personal information without my authorization	1.104	22.162	<0.001
Improper access	The databases are not protected from unauthorized access	1.000	-	-
(F7)	Providers generally do not devote enough effort for preventing unauthorized access	0.918	31.598	<0.001
	Websites can be hacked and leak personal information to the public	0.946	31.696	<0.001
Trusting beliefs	They will keep my best interests in mind when dealing with my personal info	1.000	-	-
(F8)	They fulfill their promises related to my personal info	1.014	28.590	<0.001
	They are predictable/reliable for the usage of my personal info	1.013	26.574	<0.001
Human impact on	If things continue on their present course, we will soon experience a major env crisis	1.000	-	-
environment (F9)	People have been giving little attention to how economic progress damaging the env.	1.246	13.070	<0.001
	The negative env. effects of economic growth should be considered by politicians	1.067	12.916	<0.001
Trust in travel Info	Better travel information helps to reduce traffic congestion	1.000	-	-
Technology (F10)	The internet technology reduces people's daily travel	1.181	15.165	<0.001
	Better travel information is useful to travel in a greener way	1.113	12.426	<0.001
Personal	At home, I control the heating system so the temp is not too high	1.000	-	-
conservation	I always turn off the light when I leave the room	1.006	8.891	<0.001
behavior (F11)	I save water as much as I can	1.426	8.943	<0.001
	I recycle waste as much as I can	0.952	7.175	<0.001
Environmental	I believe that social and environmental campaigns make a difference	1.000	-	-
movement activism	I am prepared to help out in environmental campaigns	1.273	17.434	<0.001
(F12)	I sign petitions or donate money to support an environmental issue	1.308	15.842	<0.001

Table 2-E Estimates of the measurement equations of the latent constructs

Table 2-F presents the relationships between the first-order factors and information privacy concern according to the conceptual model shown in Figure 2-2.

Factor name		*est.*	*C.R.*	*p-value*
Information privacy concern (F13)	Information collection (F5)	1.000	-	-
	Secondary usage (F6)	1.063	15.872	<0.001
	Improper access (F7)	1.040	13.186	<0.001
	Trusting beliefs (F8)	-0.489	-9.003	<0.001

Table 2-F Factor loadings of the information privacy concern construct

Table 2-G shows the structural equations linking the latent variables of ERG, information privacy concern and perceived usage difficulties to individual characteristics. Table 2-H shows the structural equations relating the ERG needs with environmental attitude, as well as the intention to use the "GREEN account" with the ERG needs and perceived barriers. In Tables 2-G and 2-H, a threshold of p-value < 0.1 was used to decide which factors would be left in the model.

Factor name		*est.*	*C.R.*	*p-value*
Trip efficiency improvement (F1)	Male	-0.170	-2.734	0.006
	Age 30-39	-0.341	-4.096	<0.001
	Age 40-49	-0.437	-4.758	<0.001
	Age 50-59	-0.462	-4.838	<0.001
	Age 60+	-0.461	-4.186	<0.001
	Transit use frequency: Daily	0.143	1.759	0.079
	Transit use frequency: 2-3 days a week	0.185	1.999	0.046
	Car use frequency: Daily	0.201	2.708	0.007
	Car use frequency: 2-3 days a week	0.264	2.819	0.005
Social self-concept development (F2)	Male	0.120	1.699	0.089
	Traveling with adult partner: 2-3 days a week	0.277	2.505	0.012
Eco-travel promotion (F3)	Male	-0.101	-1.982	0.048
	Income: Low	0.245	3.400	0.001
	Income: Medium	0.114	1.812	0.070
	Family with children	0.191	3.462	0.001
	Travel distance	-0.044	-2.388	0.017
	Bike use frequency: Daily	-0.227	-3.706	<0.001
Perceived usage difficulties (F4)	Male	0.142	3.256	0.001
	Age 60+	0.197	2.585	0.010
	Income: Low	-0.167	-2.852	0.004
	Income: Medium	-0.122	-2.238	0.025
	Transit use frequency: Daily	-0.156	-2.994	0.003
	Transit use frequency: 2-3 days a week	-0.135	-2.062	0.039
	Bike use frequency: Daily	-0.166	-3.307	0.001
	Bike use frequency: 2-3 days a week	-0.159	-2.706	0.007
Information privacy concern (F13)	Age 40-49	0.133	1.807	0.071
	Age 50-59	0.272	4.018	<0.001
	Age 60+	0.322	3.534	<0.001
	Number of membership cards	-0.041	-1.708	0.088

Table 2-G Linkage between individual characteristics and the ERG needs and perceived barriers

Dependent (mediator) variables	Explanatory variables	*Direct effect*			*Total effect*		
		est.	*C.R.*	*p-value*	*est.*	*C.R.*	*p-value*
Trip efficiency improvement (F1)	Trust in travel Info technology (F10)	0.436	5.658	<0.001	0.436	5.658	<0.001
	Personal conservation behavior (F11)	0.202	2.293	0.022	0.202	2.293	0.022
Social self-concepts development (F2)	Trip efficiency improvement (F1)	0.448	9.068	<0.001	0.448	9.068	<0.001
	Trust in travel Info technology (F10)	-	-	-	0.195	4.595	<0.001
	Personal conservation behavior (F11)	-	-	-	0.091	2.226	0.026
	Environmental movement activism (F12)	0.574	7.747	<0.001	0.574	7.747	0.000
Eco-travel promotion (F3)	Trip efficiency improvement (F1)	0.396	7.243	<0.001	0.490	9.405	<0.001
	Social self-concepts development (F2)	0.208	6.515	<0.001	0.208	6.515	<0.001
	Human impact on environment (F9)	0.138	2.488	0.013	0.138	2.488	0.013
	Trust in travel Info technology (F10)	0.452	6.555	<0.001	0.666	8.478	0.000
	Personal conservation behavior (F11)	-	-	-	0.099	2.242	0.025
	Environmental movement activism (F12)	-	-	-	0.119	4.791	0.000
Intention to use the "GREEN account"	Trip efficiency improvement (F1)	-	-	-	0.272	7.856	<0.001
	Social self-concepts development (F2)	0.098	2.227	0.026	0.195	4.812	<0.001
	Eco-travel promotion (F3)	0.466	6.677	<0.001	0.466	6.677	<0.001
	Perceived usage difficulties (F4)	-0.826	-6.477	<0.001	-0.826	-6.477	<0.001
	Information privacy concern (F13)	-0.197	-3.106	0.002	-0.197	-3.106	0.002
	Human impact on environment (F9)	-	-	-	0.064	2.194	0.028
	Trust in travel Info technology (F10)	-	-	-	0.329	5.795	<0.001
	Personal conservation behavior (F11)	-	-	-	0.055	2.192	0.028
	Environmental movement activism (F12)	-	-	-	0.112	3.824	<0.001

Table 2-H Linkage between the ERG needs, perceived barriers, environmental attitude and the use intention

Figure 2-3 displays the path diagram of the model structure. The full path diagram is reported in Appendix 2.C.

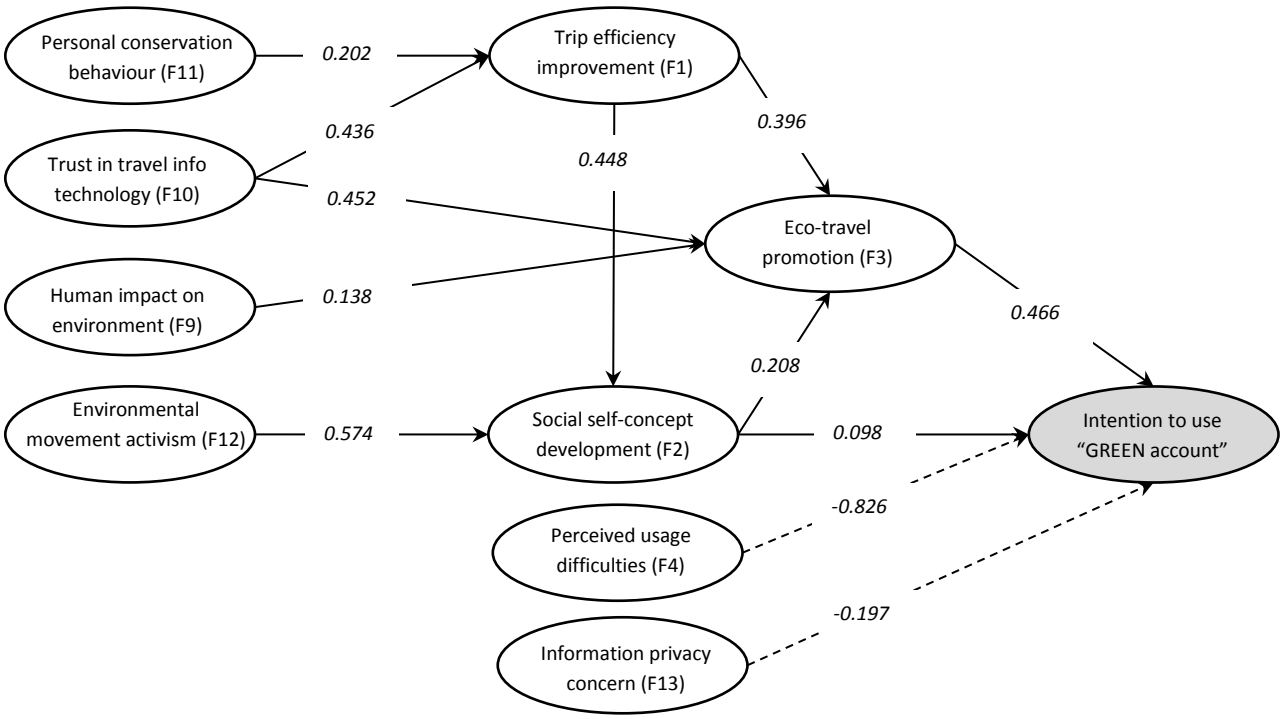


Figure 2-3 Model structure

The relation between the ERG needs, perceived barriers and individual characteristics

As shown in Table 2-G, trip efficiency improvement is higher for individuals who travel more frequently with car and public transport. The results also show gender and age effects as the moderating variables between the functional motivation and individuals' intention to use the app. These two variables have been widely explored by previous technology acceptance studies (refer to the literature review by Williams et al. (2015)).

Developing social self-concepts is associated positively with individuals who travel 2-3 days a week with another adult i.e. friends, colleagues, partners and spouse. The results also show that the social motivation is stronger for men. Since the social attributes of the app mostly include information-sharing, the reason could be explained by different motives for using social media as a means of self-presentation. Men are more likely to use social networking for making new friends while women reported using them more for relationship maintenance (Haferkamp et al., 2012; Muscanell and Guadagno, 2012). Hence, men appear to perceive the sharing of collected eco-points, CO2 emission savings etc., more importantly as this feature would enable them to enlarge their social network and communicate with new people.

Eco-travel promotion relates negatively to men and increasing travel distance, and positively to low and middle income rather than high income, indicating differences in eco-travel self-efficacy. Previous studies asserted that women, residents with shorter travel distance and with high income are more likely to adopt environment-friendly travel (e.g., Clark et al., 2016; López-Mosquera et al., 2015; Prillwitz and Barr, 2011; Yang et al., 2013). When it comes to gender and travel distance, the results are in line with recent studies, while it is the opposite for income. This can be explained by the attractiveness of the gamification elements (i.e. offered incentives and rewards) for the lower income groups. For example, the construct of usage difficulties which includes consumer's perceptions of the gamification is less important for the lower income groups which can support this argument. Furthermore, car ownership may be considered as another reason for the opposite finding. Since the respondents were not asked about their car-ownership in the survey, its effect can be deduced from the results of two previous studies. Halldórsdóttir et al. (2011) investigated the mode choice behavior of citizens in the Greater Copenhagen Area and found that the bicycle mode choice is negatively linked to car ownership. Another study in the same region by Knudsen (2015) supported a positive relationship between income and car ownership. Since car ownership increases with higher incomes, it may have a negative effect on the motivation of this group for eco-traveling. Eco-travel promotion is stronger for families with children, possibly due to the need to serve as role models. Environmental motivation is perceived as weaker for daily cyclists. This result can be explained, as individuals who bike daily already use a sustainable and healthier travel choice and, accordingly, contribute to CO2 emissions reduction. They may not feel capable of changing travel behavior toward a healthier and greener pattern due to the level of difficulty of the behavior change (i.e. self-efficacy expectancy; Bandura, 1991).

When it comes to the barriers, the usage difficulties are more significant for men and the oldest group, while they are perceived less significant for frequent public transport and bike users as well as lower

income groups. When the number of respondents' membership cards increases, they become less concerned about information privacy issues. The study results also show that privacy concern is more important for older ages. In the online context, recent literature reported that younger and older adults are different in the level of privacy concern, awareness of privacy issues and data protection (Blank et al., 2014; Lee and Coughlin, 2015; Park, 2015; Zeissig et al., 2017). Older adults show higher levels of concern, a more active protection behavior and lower self-efficacy in privacy control (Zeissig et al., 2017) which may trigger to avoid or stop the use of online tools (Lee and Coughlin, 2015).

The relation between the ERG needs, environmental attitude, perceived barriers and intention to use

As displayed in Table 2-H and Figure 2-3, the model structure supported hypothesis H1 that the perceived functional and psychological user needs relate positively to the adoption intention. It indicates that acceptance and use of the VTBC-based travel app is associated not only with functional motivation but also with psychological motivations. The specific results show that the adoption intention is linked directly to the higher order needs of eco-travel promotion and social self-concept development, while trip efficiency improvement did not show a direct causal effect. The two factors play the role of mediators between the perceived functional need and the adoption intention. It means that a greater perception of the benefits of the app to increase trip efficiency leads to a greater perception of its benefits to develop social self-identity as well as eco-travel self-efficacy which, in turn, translates into adoption. Such relationship between these three groups of core needs agree with Alderfer's ERG model of human needs in which the existence and relatedness needs are satisfied and the two are significant in developing growth needs.

The model structure confirmed hypotheses H2 and H3 that the perceived barriers relate negatively to the adoption intention. Information privacy concern is negatively related to the use and acceptance of the app, suggesting that individuals with a higher level of privacy concerns are less likely to register for the "GREEN account". Likewise, individuals who perceive the usage difficulties of the app as important are less likely to use the account. In the survey, the items concerning the usage difficulties were primarily about the individual interest in running the app as well as the offered incentives. The coefficient for the effect of this construct on the use intention is the highest negative one, indicating its key importance as a reason against VTBC-based travel app adoption.

The model also supported hypothesis H4, in which perceived user needs mediate the effect of environmental attitude on adoption intention. Strong positive attitude toward travel information technology had a positive influence on both perceived functional and growth needs. Having favorable attitudes toward travel information technologies (i.e. as an effective tool to reduce traffic congestion, avoid unnecessary daily travel and encourage eco-friendly travel) is likely to help them gain a positive evaluation of the app for either improving trip efficiency or promoting green travel.

Individuals who are aware of, or concerned about, the consequences of environmental problems perceive the value of the app to promote environmental friendly travel behavior as more important. Previous studies assert that environmental awareness tends to form favorable attitudes toward

environmentally responsible behavior (Han and Yoon, 2015; Kim and Han, 2010; Lin and Syrgabayeva, 2016).

A big interest in, and desire, to engage in organized action relates positively to the perceived relatedness needs. Volunteerism research and theory suggest that personal basic goals and needs vary across a population. This is significant in understanding the motivations that drive people to take up causes and social action. To the extent that people perceive good correspondence between their volunteering and personal motivations and goals, they are likely to engage in those activities (Mannino et al., 2010; Omoto and Snyder, 2016; Stukas et al., 2009). Asah and Blahna (2012) argued that environmental protection is only an important motivator when coupled with community, social and personal goals. In their study, the protection of the environment was less of a motivator than the human goals such as social interaction. Other studies also pointed out the significant role of social interaction motivations for participation in organized environmental actions (Bramston et al., 2011; Measham and Barnett, 2008). In our study, a big personal interest in, and desire to, support and participate in environmental actions appears to form positive attitude toward social attributes of the app and its value for social interaction.

When it comes to the relationships between the environmental attitude and the ERG needs, the findings are in line with the expectations except for the construct of “Personal conservation behavior”. Prior studies have shown that performing pro-environmental behavior strengthens environmental self-identity i.e. “more strongly see himself or herself as the type of person who will act environmentally-friendly and consequently be more likely to act pro-environmental” (van der Werff et al., 2014, 2013a, 2013b). Our result suggests that individuals that exhibited a more conservation-oriented behavior appear to perceive the functional value of the app as more important than the value of promoting eco-travel behavior. Although there is no straightforward explanation, the intuition behind this result can be explained by the negative spillover effect whereby one pro-environmental behavior deters performing additional pro-environmental behaviors (Thøgersen and Crompton, 2009; Truelove et al., 2014).

In summary, these results suggest that environmental attitude, user’ needs, perceived barriers and intention to use a VTBC-based travel app are associated. Based on these data, it can be inferred that an individual's perceived needs toward the use of the travel app are highly relevant to the individual's general attitudes of performing conservation behavior, environmental awareness, trust in travel information technology and support of organized environmental actions that influence its adoption. Furthermore, behavioral intention to use the travel app is positively directly affected by psychological needs and indirectly by functional needs. Likewise, the behavioral intention relates negatively to perceived barriers of usage difficulties and information privacy concern.

2.8. Limitations and future direction

While our study provides important insights, the evaluation of the study in light of its limitations is noteworthy. Firstly, this study did not include a population representative sample which is mainly related to the data collection and distribution method. Future research should address this issue.

Moreover, the data were collected focusing on daily commuters. It would be useful to replicate this study using other travel purposes in order to better attain the robustness of the results across travel purposes. The relations found in this study for Denmark could also be validated in cross-cultural settings due to possible cultural differences in perceptions.

Secondly, the exclusive focus on individuals and their responsibility to promote sustainable mobility neglects the social dynamics outside the system condition and the need for change at other scales beyond the individual user (Brynjarsdottir et al., 2012; Gabrielli et al., 2014). The approach is reasonable considering the role of individualism in Danish society. We encourage future researchers to explore the role of communities and collective efficacy and responsibility in addition to individual responsibility.

Lastly, the proposed app is currently under development, and during the survey administration, the new travel app has not yet been deployed. Hence, the study focuses on the pre-adoption stage. Additional research is required to employ a longitude design to investigate post-adoption behavior. It is essential to appraise the long-term effects of such technologies on travel behavior modifications.

2.9. Conclusion

The prevalence of smartphone use, the rise in mobile device sensors and the popularity of social networks for sharing information have pushed decision makers into thinking that collaborative travel apps could be a key to promote behavior change toward eco-friendly travel modes. However, the literature review revealed a lack of understanding about how individuals are motivated to accept and adopt VTBC-based travel apps as well as the challenges related to user attraction.

This study provides empirical evidence that user attraction and engagement are associated with the ability of the travel app to satisfy functional and psychological human needs of relatedness and growth. Comparable to Noppers et al (2014), who investigated three groups of motivations for adopting sustainable innovations, we show that also for VTBC-based travel apps, the use intention is explained by functional, social and environmental motives. More specifically, a good evaluation of the ability of the app to improve trip efficiency leads to a good evolution of its social and environmental attributes and, in turn, translates into its adoption.

Thus, the results support the hypothesis that the adoption of VTBC-based travel apps is not exclusively guided by their functional utility, but also by their ability to satisfy emotional needs by triggering feelings of sense of belonging, social identification and developing environmental self-identity as well as eco-travel self-efficacy. It highlights self-monitoring, information sharing and gamification elements (i.e. incentives and rewards) as appealing persuasive strategies promoting and driving engagement, which should therefore be stressed throughout the process of system development, business design and marketing.

Furthermore, the results show that the barriers embedded in the attributes of the travel app negatively influence its adoption. In other words, the study shows the need for consideration of reasons against, together with reasons for, in order to better explain the adoption of the VTBC-based travel app. Two

dimensions that seem to have influence in the appraisal of acceptance of the app, relate with low usage risk and high usability.

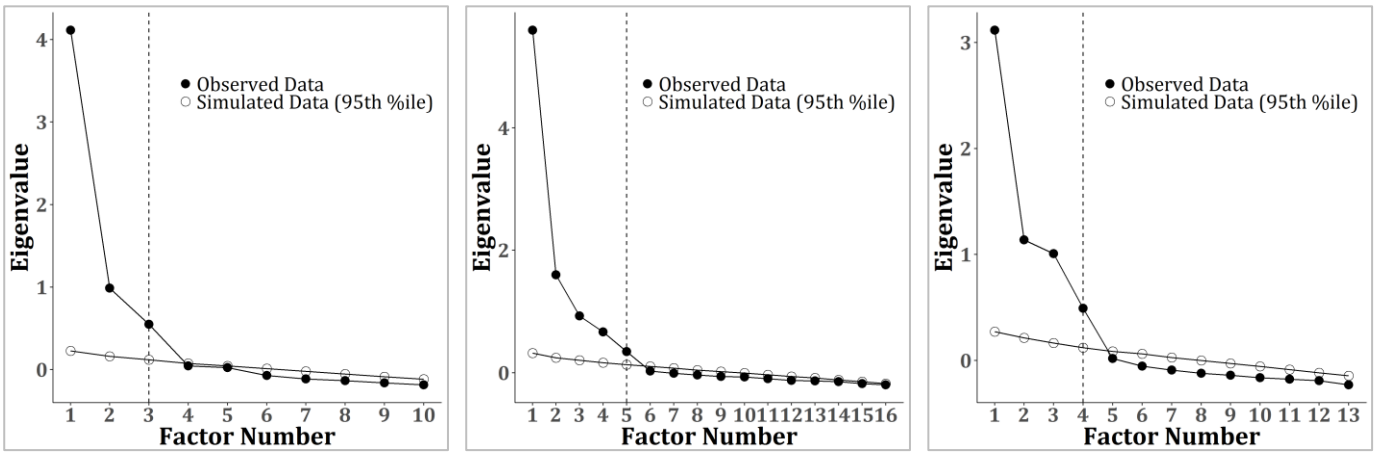
The findings also imply that environmental awareness, favorable attitude toward travel information technologies, performing conservation behavior, and a personal desire to participate in organized environmental activities, affect individuals' perceptions of the benefits of the travel app and play a significant role in explaining their adoption decision formation. The study has also provided authorities and app designers with an understanding of different user groups, which aspects of VTBC-based travel apps they value and accordingly their motivations and barriers for using them.

Acknowledgement

The study is supported by the PhD dissertation scholarship financed by the City of Copenhagen. We appreciate the reviewers for dedicating the time and effort for assisting us improving the paper, especially in terms of broadening our references to existing knowledge and improving its readability

Appendix 2.A

Figure 2-4 shows the scree plot/parallel analysis of the indicators of the model, implemented by R package "psych". The vertical line indicates parallel analysis suggested maximum number of factors to retain.



(a) ERG needs (b) Perceived barriers (c) Environmental attitude

Figure 2-4 Scree plot/parallel analysis for the indicators of the model

Appendix 2.B

Description	Mean	St.Dev	Skew	Kurtosis	Shapiro-Wilk statistic*
It would save me travel time	2.977	1.061	-0.082	2.360	0.913
It would make my trip cheaper	3.158	1.053	-0.269	2.559	0.908
Sharing my CO2 savings and burnt calories on social media could be fun	2.344	1.225	0.495	2.103	0.867
I could enlarge my social network with sharing my trip information	2.209	1.065	0.549	2.529	0.871
I would feel part of the community	2.866	1.145	-0.162	2.171	0.903
I could help others by sharing my CO2 savings on social media	2.489	1.141	0.298	2.252	0.897
It would help me make healthier travel choices	3.489	1.066	-0.638	2.823	0.877
It would help me make greener travel choices	3.646	1.082	-0.784	3.058	0.862
I could contribute to the city vision for CO2 level reduction	3.835	0.855	-1.072	4.772	0.806
"GREEN account" would make my trip more environmentally friendly	3.667	0.997	-0.849	3.535	0.853
I would not like to run the app while travelling	2.903	0.916	0.267	2.860	0.891
Trying to earn eco-points could be stressful	2.566	0.989	0.359	2.676	0.897
The offered incentives do NOT answer my needs	2.452	1.067	0.521	2.636	0.889
"GREEN account" is too time consuming compared to the benefits	2.845	0.811	0.098	3.781	0.845
It bothers me when they ask me for personal information	3.466	1.065	-0.386	2.416	0.896
I think twice about providing my personal information	4.161	0.791	-0.967	4.131	0.795
I am concerned they collect too much information about me	3.786	1.001	-0.561	2.659	0.873
My personal information could be used for other purposes	3.903	0.910	-0.937	3.750	0.821
Providers could sell my personal information to third parties	4.014	1.014	-1.019	3.508	0.818
Providers could share my personal information without my authorization	3.994	1.008	-0.951	3.322	0.825
The databases are not protected from unauthorized access	3.986	0.988	-0.836	3.091	0.838
Providers generally do not devote enough effort for preventing unauthorized access	3.808	0.950	-0.354	2.404	0.873
Websites can be hacked and leak personal information to the public	3.824	1.015	-0.662	2.780	0.864
They will keep my best interests in mind when dealing with my personal information	3.126	0.911	-0.442	2.831	0.877
They fulfill their promises related to my personal information	3.258	0.852	-0.508	3.186	0.863
They are predictable/reliable for the usage of my personal info	3.143	0.861	-0.448	3.184	0.867
If things continue on their present course, we will soon experience a major env. crisis	3.990	0.929	-0.913	3.636	0.833
People have been giving little attention to how economic progress damaging the env.	4.002	0.936	-0.864	3.332	0.833
The negative env. effects of economic growth should be considered by politicians	4.262	0.827	-1.275	5.063	0.770
Better travel information helps to reduce traffic congestion	3.960	0.762	-0.903	4.764	0.800
The internet technology reduces people's daily travel	3.606	0.925	-0.51	3.103	0.879
Better travel information is useful to travel in a greener way	3.924	0.782	-0.867	4.514	0.811
At home, I control the heating system so the temp is not too high	3.902	0.948	-0.997	3.925	0.827
I always turn off the light when I leave the room	4.256	0.817	-1.061	4.011	0.785
I save water as much as I can	3.941	0.885	-0.701	3.245	0.849
I recycle waste as much as I can	4.157	0.930	-1.101	3.877	0.798
I believe that social and environmental campaigns make a difference	3.594	0.842	-0.596	3.515	0.855
I am prepared to help out in environmental campaigns	3.216	0.960	-0.205	2.780	0.901
I sign petitions or donate money to support an environmental issue	3.017	1.146	-0.154	2.212	0.913
Mardia test	Statistic		P-value		
Mardia Skewness	20796.51		<0.001		
Mardia Kurtosis	73.97		<0.001		

** The Shapiro–Wilk test statistic is significantly different than unity at the 0.01 significance level for all the items.*

Table 2-I Univariate and multivariate normality tests for the attitudinal items.

Appendix 2.C

Figure 2-5 shows the full path diagram of the model. The acronym of indicators is according to the items described in Tables 2-B, 2-C and 2-D.

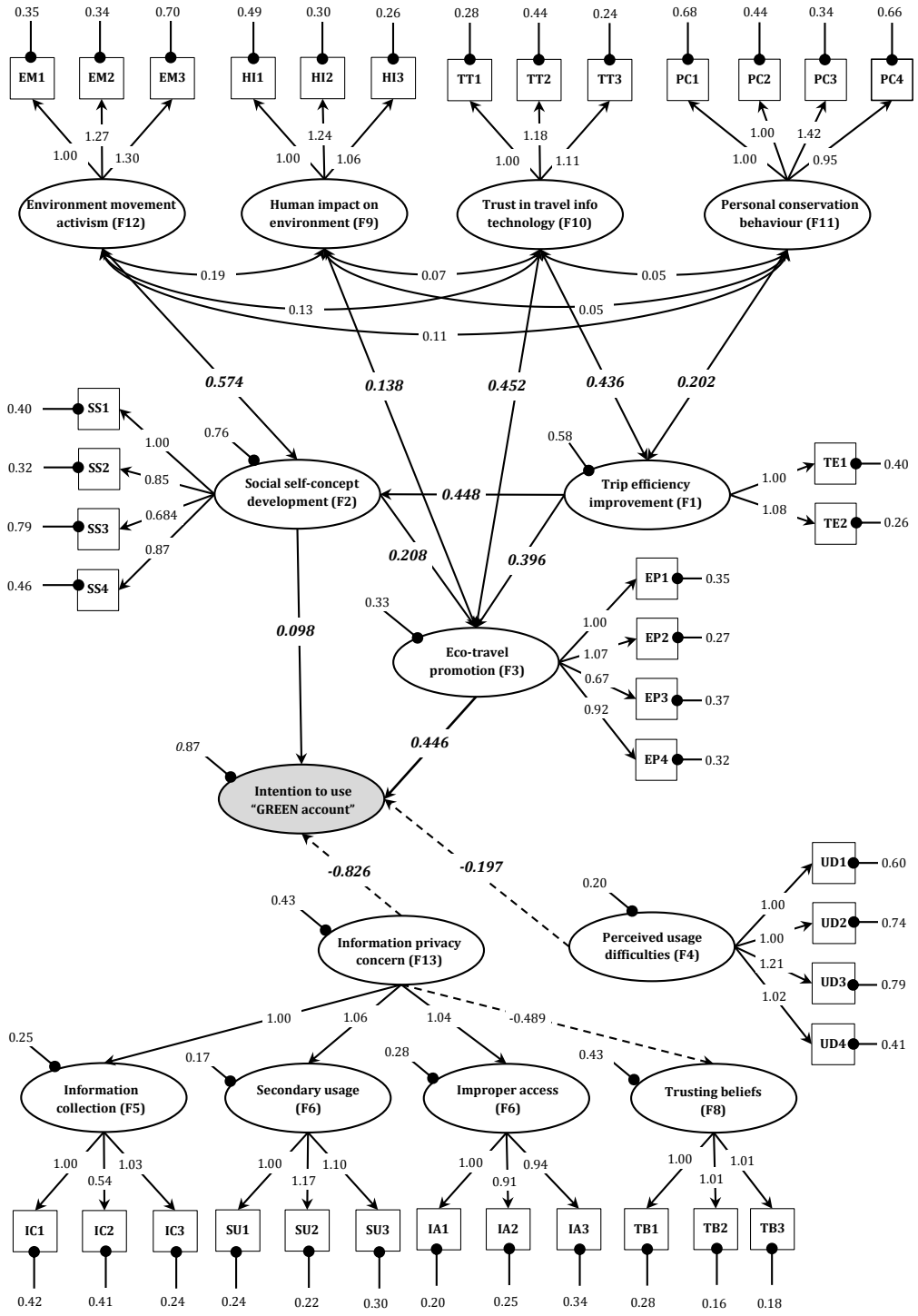


Figure 2-5 Full path diagram of the model

Note:

Positive relation ⟶ *Negative relation* - - - -▸ *Residual variance* —● *Correlation* ⟷

3. Use Intention of Mobility-Management Travel App: The Role of Users Goals, Technophile Attitude and Community Resilience

Based on the submitted paper below:

Mehdizadeh, A., Kaplan, S., Silva, J. D. A. E., Nielsen, O. A. & Pereira, C. P (2018). Use intention of mobility-management travel app: the role of users goals, technophile attitude and community resilience. Submitted to *Transportation Research Part A: Policy and Practice.* September 26, 2018.

Presented at
6th Symposium of the European Association for Research in Transportation (hEART conference), Haifa, Isreal, September 12-14, 2017.

mobil.TUM 2018- International Scientific Conference on Mobility and Transport, Munich, Germany, June 13 - 14, 2018.

ABSTRACT

In recent years, one of the solutions that have received a lot of attention to motivate change for sustainable urban mobility is persuasive interventions delivered through mobility-management tools. However, understanding the motivators underlying individuals' intentions to use persuasive tools is essential to evaluate the efficacy of this solution for supporting sustainable travel behavior. This paper aims to pinpoint and understand the drivers that influence individual travel decisions when using travel app including both travel information and persuasive features. The analytical framework relies on the goal-framing theory in which individual's motives to use the app are grouped into three overarching goals namely, 1) gain, 2) hedonic and 3) normative goal-frames. Furthermore, technophile attitude and community resilience constructs are incorporated in the framework in order to better explain user-sided heterogeneity. The case-study focuses on the new travel information system in Copenhagen (Denmark). It questions 822 Danish citizens by distributing a technology-use preference survey. Structural equation models revealed that the choice drivers are specific to individual users and depends on wide ranging factors that go above traditional economic and socio-demographic methods. The study revealed that first, trip efficiency improvement, enjoyment, social interaction and eco-friendly travel promotion are important motives to use the new app. Second, there are different intentions among individuals according to the perceived value of the new information system as well as travel purposes. Third, technophile attitude exerts a positive influence on both users' motives and use intention. Fourth, the social dynamic behind the system, captured by the community resilience constructs, influence the use intention of the travel app.

Keywords: ATIS; behavior change; Travel information; Structural equation; Goal-framing theory

3.1. Introduction

The use of information-based mobility management strategies have been suggested already in the beginning of the millennium but have been gaining momentum only in the last decade. Gärling et al. (2004, 2002) described a range of advanced traveler information systems (ATIS) for mobility-management including navigation applications (apps) that notify the driver regarding route alternatives and alerts, sharing information regarding joint trips, real-time information regarding public transport, voluntary travel behavior change programs (VTBC) - also known as individualized marketing, and travel role-modelling through social networks. These information-based strategies, besides their low-cost to decision makers and wide availability to the general public, are potentially powerful from the behavioral perspective.

Problem awareness by giving information affects perceived responsibility, behavioral control and social norms. This, in turn, affect behavioral intentions and actions (Bamberg et al., 2011; Eriksson et al., 2006). Hence, information technologies and individualized marketing are important tools in leading toward sustainable travel behavior. As they belong to commitment-oriented strategies, they are also more likely to be implemented because of their political acceptability (Gärling et al., 2004). They do not involve the ethical and normative issues which usually impede the public acceptance of pricing or monetary reward schemes (Di Ciommo et al., 2013; te Brömmelstroet, 2014). They encourage informed decisions, thus encouraging people to make a rational choice based on costs and benefits (Steg and Vlek, 2009), and make "the right choice for the right reasons" thus satisfying higher-order emotional needs of self-actualization that are important in long-term behavioral shifts (te Brömmelstroet, 2014). Further, tailor-made travel plans can alleviate contextual difficulties and induce temporary travel shifts so that people can reconsider their habitual behavior (Steg and Vlek, 2009).

Traditional VTBC solutions require person-based interaction, either by phone or home interviews, which is inherently expensive and may induce biases stemming from social interaction and communication. ATIS assisted VTBC offers opportunities to reduce the costs associated with the need for human-based interaction. The widespread Internet connectivity, the common use of smartphones, and the frequent use of mobile travel apps provide an opportunity for producing a critical mass for VTBC-based ATIS. While most travel apps are still based on the traditional view of digitized traffic information, the newest generation of ATIS include user-based alerts, prescriptive advices (e.g., route alternatives and changes), reflective memory (e.g., the ability to save past and future trips and locations), and persuasive strategies inspired by Fogg's framework (Fogg, 1998, 2003) in which, the system design is persuasive and explicitly attempts "to change attitudes or behaviors or both (without using coercion or deception)". This is achieved by raising awareness of individual choices, patterns, and the consequences of activities. Persuasive technologies monitor human activities in relation to resource usage, and provide information to the user for the purpose of motivating behavioral change. Travel mobile apps incorporating persuasive strategies are currently under development and offer functions for

i. Self-monitoring and feedback in terms of health and environmental information e.g., SUPERHUB (Gabrielli and Maimone, 2013), IPET (Meloni et al., 2014), Peacox (Bothos et al., 2014), Quantified Traveler (Jariyasunant et al., 2015), Tripzoom (Poslad et al., 2015), MM (Nakashima et al., 2017) and Optimum (Anagnostopoulou et al., 2018)
ii. Challenges & goal setting e.g., SUPERHUB, Peacox and TRIPZOOM,
iii. Tailoring information according to the user's needs, usage context and interests e.g., SUPERHUB, IPET and Peacox,
iv. Social comparison & networking e.g., Quantified Traveler, SUPERHUB, Peacox, TRIPZOOM, MM, Optimum
v. Gamification & rewards e.g., SUPERHUB, Peacox, ViaggiaRoveretgoto (Kazhamiakin et al., 2015), TRIPZOOM, MM, and SMART (Huang et al., 2018).

Although these new solutions may produce concerns regarding technology, privacy, reliability (Gadziński, 2018) and unintended externalities (te Brömmelstroet, 2014), field experiments provide evidence that these new features are important in influencing users to change their travel behavior (Gabrielli and Maimone, 2013; Jariyasunant et al., 2015; Kazhamiakin et al., 2015; Poslad et al., 2015; Nakashima et al., 2017; Huang et al., 2018) .

Gabrielli and Maimone (2013) explored the impact of "SUPERHUB" as persuasive mobile app, on transport choices and habit through a small pilot study in Switzerland. By Analyzing mobility habits logs as well as interviews, they found a modest increase (14%) in "sustainable transport choices" over a month. However, its long term effect to change and maintain the desired behavior is an important issue. Jariyasunant et al. (2015) investigated the implementation of a mobility-management tool named "Quantified Traveler" applied in San Francisco Bay. The Quantified Traveler has a computer-based platform for travel diary collection and feedback through mobile application; it still relies much on human assisted travel tailoring. Three weeks field experiment proved that among participants, "Quantified Traveler" is useful to significantly reduce the car mileage to a lesser extent encourage walking/cycling. Kazhamiakin et al. (2015) explored the use of "ViaggiaRoveretgoto", a gamified intervention mobile app, to change travel behavior in terms of route and mode choices through a control experiment during five weeks. The analysis of the system logs showed that gamification could increase engagement and possibly promote sustainable mobility behaviors. Poslad et al. (2015) studies the impact of different travel incentives through the use of "Tripzoom" app on motivating users to embrace sustainable mobility in the cities of Enschede, Gothenburg and Leeds for a period of six months. The main findings support the effectiveness of the incentives to encourage travel behavior change. However, providing users with customized information, feedback and goals aligned with their specific needs were found essential to trigger behavior change. Additionally, appealing and simple design appeared to be important to the users. Nakashima et al. (2017) investigated the effect of the mobile app of "MM", with the function of gamification and comparison including scoring, ranking and competition in changing travel behavior (i.e. increasing number of steps) through a before-after study design. The results revealed that the effectiveness of the app in changing behavior depends on users'

current walking behavior as well as their personality. More specifically, this was effective for people who do not usually walk too much and particularly for people who have a competitive personality. Huang et al. (2018) studied the impact of persuasive incentives, delivered through the mobile app of "SMART", on cycling behavior in the Twente region of the Netherlands. The gamification and rewards functions of the app were reported to affect travel behavior and increase cycling. Furthermore, providing customized incentives according to users travel pattern were found important to trigger behavior change.

This paper focuses on exploring the motivation to use a new real-time multi-modal travel app for Copenhagen, as ATIS for digital mobility-management assistance, aimed at encouraging travel behavior change. The new multi-modal travel app for Copenhagen, as VTBC-based ATIS, is a multi-faceted mobile app including both travel information and persuasive strategies such as health and environmental feedback, tailoring travel options, self-monitoring, tunneling users toward green behavior, social networking, nudging and gamification elements. With this respect it is similar to the abovementioned mobile apps. Due to the collaborative feature of these new generation of travel apps, a critical mass is essential for market penetration and use (see Dickinson et al., 2015). Meloni and Teulada (2015) describe three behavioral change elements that may induce target behavior through using ATIS: motivation, ability and triggers for behavioral change. A better grasp of the motivators and barriers for ATIS market penetration will aid authorities and private entrepreneurs to design effective and appealing ATIS, eventually translating into to wider potential of VTBC.

Tailoring the travel solutions that support individual needs and expectations can possibly lead to a powerful potential travel shift toward eco-friendly solutions. There is a wide agreement that satisfying user needs are fundamental for the design, implementation and dissemination of mobility-management travel apps aimed at encouraging VTBC (Gabrielli et al., 2014; Grotenhuis et al., 2007; Kramers, 2014; Meloni and Teulada, 2015; Wang et al., 2016). This study contributes to the body-of-knowledge by offering to explore goal-framing theory (Lindenberg, 2006; Lindenberg and Steg, 2007) as a motivator for the intentions to use mobility-management travel app. In environmental context, goal-framing theory argues that, in every situation individuals want to achieve a goal which incorporates certain kinds of motives. Motives are separated into three overarching categories of goals (i.e. "focal goal" or "goal-frame") according to core desires and needs they satisfy. The goals, which are likely to be situation dependent instead of stable across situations, govern or frame "the way in which people process information and act on it". Consequently, they influence individuals' attitude, feelings and actions. The three categories of goals are gain goal-frame "to guard and improve one's resources", hedonic goal-frame "to feel better right now", and normative goal-frame "to act appropriately". Thus, intrinsic motivation to satisfy higher-order emotional needs of relatedness and growth (i.e., autonomy and competence) is an important part of goal-directed behavior (Deci and Ryan, 2000).

This study follows the same line of research as Pronello et al. (2017) who investigated the intentions to use "Optimod'Lyon" multi-modal travel app by applying the theory of planned behavior (TPB). Pronello et al. (2017) and Andersson et al. (2018) propose the Theory of planned Behavior (TPB), for explaining

the use of smartphone apps by linking beliefs and behavioral intentions. The TPB and the goal-framing theory are linked through the notion of decision factors emanating from personal identity and situational concerns. Personal identity could be studied using the theory of human needs, where the satisfaction of needs guides the motivation to engage in action (Woodbine and Liu, 2010) and the two theories can also be viewed as complementary (Gucciardi and Jackson, 2015). While simple navigation apps are mostly driven by their functional value, the general mobile app use and adoption is driven by a wide range of psychological needs: functional, safety, health, social, self-esteem and self-actualization needs (Kim and Baek, 2018; Sun et al., 2017). Hence, as recommended by Dickinson et al. (2015), this study identifies functional and psychological user needs as backbone for user attraction and engagement.

The rest of the paper is organized as follows: Section 3.2 presents and discusses the motivational factors to adopt the new system and relevant literature review to support the proposed theoretical framework and corresponding hypotheses. Section 3.3 presents the mathematical method (i.e. Structural Equation Modelling) for testing the hypotheses. Sections 3.4 and 3.5 introduce the case study, survey design, data collection as well as sample descriptions. Section 3.6 presents the results and discussions. Limitation and future direction is placed in Section 3.7 and finally, Section 3.8 concludes the paper.

3.2. Theoretical framework

3.2.1 Goal-framing theory

As mentioned earlier, goal-framing theory argues that in every situation, information processing and behavior are guided by three overarching goals namely, gain, hedonic and normative goal-frames. Gain goal-frame implies the desire to guard or improve one's resources reflecting more strategic and calculative intentions to improve one's situation in the longer run. If this goal-frame is prevailing, individuals are focused on the prospect of gaining benefits for their own interest. Individuals in a hedonic goal-frame have desire to maintain or improve feelings in the short-term and motivates them to develop their situation at the moment in terms of pleasure and mood. Hence it is connected to personal emotions. Normative goal-frame bears on the motives to guard and improve goals of the collective, act morally, behave adequately and conform to social norms and rules.

The theory also suggests that the three goal-frames and their motives are simultaneously present and active at any given time. However, only one goal-frame is dominant which determine the way individuals interpret and frame the situation and act as well. Motives belonging to the other two goal-frames are in the background and seem to interfere with the dominant one. The background goal-frames either promote (i.e. compatibility situation) or weaken (i.e. conflict situation) the main one and thereby, affecting action.

Prior empirical studies investigated how different types of motives are related to technology adoption behavior. When it comes to sustainable innovations, Han et al., (2017) presented that the monetary, performance and convenience motives have both direct and indirect effects on consumers' intention to adopt electric vehicles, whereas enjoyment, pleasure, social acceptance and normative values have only

indirect effects on the adoption intention. However, Axsen and Kurani (2013) and Jansson et al. (2010) showed that people's willingness to adopt alternative fuel vehicles is significantly influenced by the environmental values they endorse. Koo et al. (2015) investigated the impact of intrinsic and extrinsic motivators on smart green IT device use. They found that perceived enjoyment strongly correlates with the perceived usefulness which in turn, translates to its adoption i.e. indirect effect of hedonic motives on users' behavior. In another study by Yoon (2018), perceived usefulness and personal norm were integrated in to model in order to investigate individual's intention to use green IT. The results showed that the use intention is driven by both functional and normative motives.

In the context of mobile information technologies, Zhu et al. (2017) investigated important factors that influence adoption of ridesharing applications. They showed that functional values (e.g. time and monetary saving) together with emotional values (e.g. enjoyment) and social values (e.g. social image improvement) influence significantly the overall perceived value of ridesharing applications. Functional and hedonic motives were also identified by recent studies as important antecedents of intention to adopt mobile devices such as mobile applications for booking/shopping purposes (e.g. Agrebi and Jallais, 2015; Morosan and DeFranco, 2016; Ozturk et al., 2016; Wei-HanTan and Keng-Boon, 2018), mobile social networking services (e.g. Chang and Shen, 2018; Hsiao et al., 2016; Hsiao, 2017) and smartwatches (Hong et al., 2017; Hsiao and Chen, 2018).

While simple navigation apps are mostly driven by their functional value, the use of VTBC-based travel app is likely to embrace hedonic motives as well as the aspects of social responsibility and personal morality. A number of recent studies employed the goal-framing theory to explain individual environmentally responsible decision-making in the domains of transport (e.g. Bösehans and Walker, 2018; Geng et al., 2017; Han et al., 2016) and energy (e.g. Dóci and Vasileiadou, 2015; Polhill and Gotts, 2017). Hence, this study investigates different motives in the framework of goal-framing theory as backbone for user attraction and engagement. We also hypothesized that depending on the situation (which is different travel purposes in this study as presented in Table 3-C), different motives guide the use of VTBC-based travel apps.

3.2.2 Technophilia

Consumer attitudes and psychological factors can be critical for the marketing of innovative technologies which affect their success. With the purpose of analyzing these factors, we investigated the role of technophilia, an euphoric attitude toward technology referring to "a person's openness, interest in and competence with (innovative) technologies" (Seebauer and Berger, 2010). Therefore, the definition of technophilia is aligned with the ABC model of attitudes (Eagly and Chaiken, 1993) in which technophile attitude has three components namely, affective (e.g., satisfaction, anxiety or enjoyment), behavioral (e.g., experience or the frequency of usage), and cognitive (e.g., technology self-efficacy). Technophilia as a personal driver has long been studied in the research on ICT adoption behavior.

Technology self-efficacy as the cognitive attribute of technology affinity, is a personal belief in one's ability to successfully perform or learn a task when dealing with a technological device (McDonald and

Siegall, 1992). This concept emerged from Social Cognitive Theory (SCT; Bandura ,2012, 1982). Prior empirical studies investigated the effect of technology self-efficacy to predict the use of mobile applications (Alalwan et al., 2016; Dasgupta et al., 2011; Ozturk et al., 2016a, 2016b; Shareef et al., 2018; Yu, 2014; Zhu et al., 2017, 2010). The findings of these studies support a positive effect of technology self-efficacy on user's attitude and behavior. Prior literature also relates the acceptance of ICT to affective attitudes like anxiety (e.g., Briz-Ponce et al., 2017; Celik, 2016; John, 2015), enjoyment (e.g., Sánchez-Prieto et al., 2016; Zhang et al., 2015) and satisfaction (e.g., Pindeh et al., 2016; Yoon, 2016) as well as behavioral aspects (Goulias et al., 2004; John, 2015).

Zhu et al. (2017) conceptualized a behavioral model to investigate the factors influencing the use of ridesharing mobile app. SCT was used as the underpinning theory arguing that human behavior both influences and is influenced by personal factors and the environment i.e. triadic reciprocal relationships. In their proposed framework, personal factors and the environment were presented by technology self-efficacy and perceived value respectively. Figure 3-1 displays the triadic reciprocal relationships in which the solid and dotted lines denote, respectively, before-adoption and post-adoption.

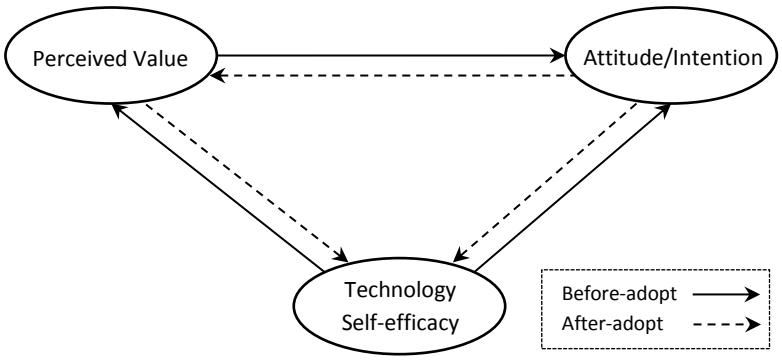


Figure 3-1 Self-efficacy based value adoption model (Source: Zhu et al., 2017)

In the phase of before adoption which is relevant to our study, while perceived value has direct effect on behavior, technology self-efficacy is the antecedent of both perceived value and behavior. Our study replaced technology self-efficacy by technophilia since both terms represent personal factors. Prior literature support both direct (e.g., Dasgupta et al., 2011; Seebauer et al., 2015) and indirect (e.g., Alalwan et al., 2016; Ozturk et al., 2016b, 2016a; Yu, 2014) effects of technology affinity on users behavior. Therefore, we hypothesized that technophilia has a positive (direct and indirect) relation with the use intention of VTBC-based travel app i.e. both adoption and situational use intentions.

3.2.3 Trust ecology and place attachment

Some critical analyses of persuasive technologies with focus on their underpinning assumptions and limitations have been acknowledged in recent studies (Gabrielli et al., 2014; Brynjarsdottir et al., 2012; DiSalvo et al., 2010; Dourish, 2010). Specifically, the main limitations appeared pertain to: (i) Absence of end-user engagement in determining the persuasive interventions for supporting behavior change. (ii) Scarcity of long-term and large-scale data sets for the evaluation of the interventions' efficacy at changing users' attitude and behavior. (iii) Exclusive focus on pursuing specific users behaviors and

choices rather than suggesting more collective approaches as to address the pertinent communities that may exert more influence on adoption behavior.

The third limitation narrows the vision of sustainability since it frames “users” as individuals, isolates them and brackets the multifaceted social, cultural, and institutional contexts where they live. Critiques have confirmed that once we widen our lens to comprehend the social, cultural and institutional influences and curbs on individuals – the failure of persuasive solutions commence. A common problem appeared is that the exclusive focus on users’ responsibility for sustainable practice, are prone to disregard the social dynamics outside the system condition and the need for change at other scales beyond the individual users (Hekler et al., 2013; Mogles et al., 2018; Pierce et al., 2010; Strengers, 2011, 2008).

To enrich the theoretical framework as well as address the third limitation, we incorporated the notion of “trust ecology” (Stern and Baird, 2015) in to the model which is the kind of trust that individuals place on each other i.e. social trust, as well as on the organizations/institutions that surround them i.e. institutional trust. Beside values, the importance of trust and its role as motivator for goal-directed behavior were highlighted by prior studies since trust reinforces peoples’ engaging behavior i.e. acceptability and public involvement (Hsu et al., 2012; Steg et al., 2015). In general, trust is built on the accumulation of social and institutional relationships and can reduce social friction and stimulate cooperation, notably where collective actions are desired such as environmental issues (Brondizio et al., 2009; Pretty, 2003; Pretty and Ward, 2001). Individuals with more social trust may have more of a tendency to pursue the common good of society, which promotes participation in collective actions. It is mainly due to the fact that they tend to believe other members will also be concerned with and collaborate to protect the common good (Stern and Baird, 2015). Likewise, when collaborative efforts are needed, people with greater levels of institutional trust are more apt to behave in a responsible manner. In that, they are inclined to rely on the credibility of public institution enacting and implementing necessary policies in a reliable manner. Previous literature investigated the role of these two forms of trust in relation to environmental policy, their acceptance and peoples engagement (Adaman et al., 2011; Brondizio et al., 2009; Jones, 2010; Pretty and Ward, 2001; Taniguchi and Marshall, 2018; Wynveen and Sutton, 2015). Trust is also contextual which may vary among issues, resources, or communities (Winter et al., 1999). Therefore, a better understanding of “trust ecology” could help in alleviating trust barriers to VTBC-based travel app as a collaborative technology. However, the relationship between these two constructs is the main problem with trust research and there is no general agreement on what is cause and what is effect. In our behavioral framework, the causal relation is grounded on the findings of the recent study conducted by Sønderskov and Dinesen (2016) in Denmark. Their findings suggest that institutional trust shapes social trust, while the evidence for a reverse relationship was limited.

Place attachment is another factor often assumed to affect residents’ attitude and behavior in relation to local issues and collaborative actions. Place attachment refers to an affective bond that people establish with specific place and it is widely viewed as an important part of human identity. Considering

people's emotional connections with the city may provide a better understanding of their motivations, reactions to, and participation in local community-based action (Manzo and Perkins, 2006; Scannell and Gifford, 2013). In this context, there are some empirical studies showing the importance of place attachment to motivate cooperative pro-environment action (e.g., Gosling and Williams, 2010), to support city management interventions (e.g., Devine-Wright, 2009; Verbrugge and van den Born, 2018) and to predict residents' engagement with climate change adaptation and mitigation activities in local scale (e.g., Amundsen, 2015; Scannell and Gifford, 2013)

As suggested by Ajzen and Fishbein (1980) as well as Bamberg (2003), general attitudes do not have a direct effect on specific behaviors but they are indirect determinant through situation-specific beliefs, operating via their impact on "the generation of situation-specific cognition". In this paper, trust ecology and place attachment are general attitudes. Therefore, we investigate their effects on the use intentions of VTBC-based travel app mediated by the three goal-frames. Figure 3-2 describes the conceptual behavioral framework. Based on the above literature support, the hypotheses related to the model are proposed as follows:

H1: There are three different groups of motives regarding the use of VTBC-based travel app which explain the use intention
H2: Technophilia relates positively to use intention
H3: Technophilia relates positively to goal-frames
H4: Social trust, institutional trust and place attachment have an effect on use intention, mediated by goal-frames
H5: Institutional trust shapes social trust in the context of transport

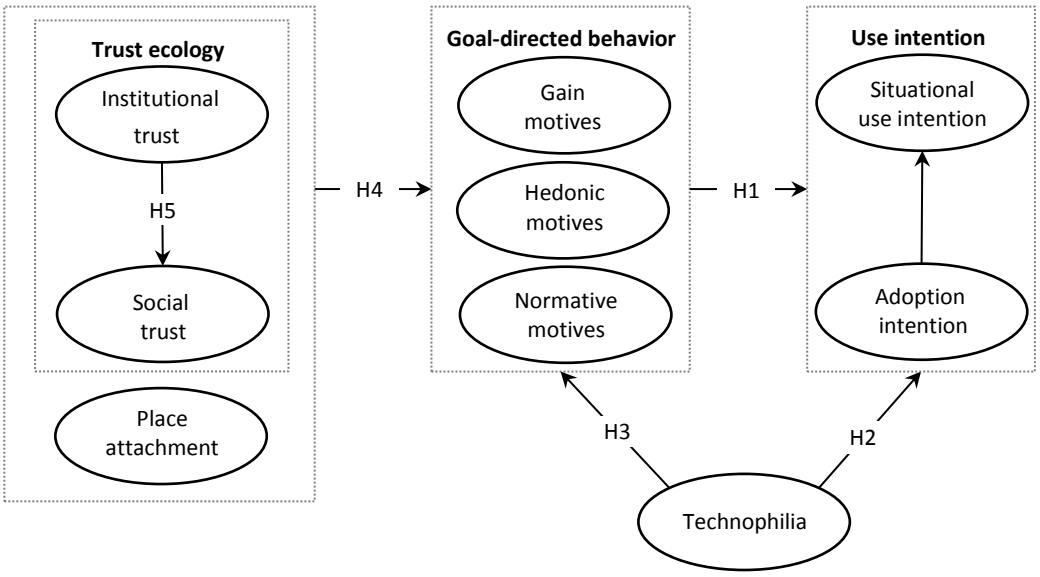


Figure 3-2 Conceptual model on motivations to use the app

3.3. Mathematical model

The behavioral model structure representing the research hypotheses was investigated by applying structural equation modeling (SEM). SEM is a confirmatory analysis technique which tests models that are conceptually derived beforehand, and evaluate how well the theory fits the collected data (Hair et al., 2006). SEM foundation lies in two multivariate techniques: confirmatory factor analysis (CFA) and multiple regressions, also called path analysis, which test simultaneously measurement and structural equations. The measurement equations denote relations between latent constructs and their respective indicators while structural equations represent the directional relations between latent constructs. An increasing number of recent studies employed SEM to examine the use of travel mobile apps (e.g., Assemi et al., 2018; Fang et al., 2017; Im and Hancer, 2017; Weng et al., 2017). In this study, the model is constructed by four equations that we explain below.

$$I_{rn} = Z^*_{ln}\,\alpha_r + \upsilon_{rn} \quad \text{and} \quad \upsilon_{rn} \sim N(0, \Sigma_\upsilon) \quad \text{for} \quad r = 1, \dots, R \tag{1}$$

$$Z^*_{ln} = X_{ln}\beta_l + \omega_{ln} \quad \text{and} \quad \omega_{ln} \sim N(0, \Sigma_\omega) \quad \text{for} \quad l = 1, \dots, L \tag{2}$$

$$Z^*_l = Z_i\beta_i + \varphi_l \quad \text{and} \quad \varphi_l \sim N\left(0, \Sigma_\varphi\right) \quad \text{for} \quad l = 1, \dots, L \;\&\; i = 1, \dots, K \tag{3}$$

$$Y_n = Z^*_{ln}\gamma_Z + \xi_n \quad \text{and} \quad \xi_n \sim N\left(0, {\sigma_\xi}^2\right) \tag{4}$$

Where Eq. (1) links the measurement indicators (i.e. questionnaire items) to the latent constructs. I_{rn} refers to the value of an indicator *r* related to latent construct Z^*_{ln} as perceived by respondent *n.* The value of latent construct *l* for respondent *n* is labeled with Z^*_{ln} and α_r is the corresponding factor loading. The error term is expressed as element υ_{rn} which is of a vector following a normal distribution with covariance matrix Σ_υ. Eq. (2) links the latent constructs Z^*_{ln} to individual characteristics. X_{ln} is a vector of the respondents' individual characteristics (e.g. socio-economic and travel habit) and β_l are the parameters representing the regression relations. The error term is ω_{ln} which is a vector following a normal distribution with covariance matrix Σ_ω. Eq. (3) relates the explanatory latent constructs Z_i (e.g., technophilia, institutional trust, social trust and place attachment) with the mediator latent constructs Z^*_l (e.g. the goal-frames) through parameters β_i. The error term is φ_l following a normal distribution with covariance matrix Σ_φ. Eq. (4) represents regression relations between the latent constructs Z^*_{ln} and the target variable Y_n through parameters γ_Z. Here, Y_n is the likelihood level of using the app by respondent *n* (i.e. in 1-5 Likert scale from highly unlikely to highly likely). The error terms is presented as ξ_n.

The commercial software M-Plus were used to estimate the model parameters (Muthén and Muthén, 2012). The parameters of the four sets of equations were estimated simultaneously by Mean-and Variance-adjusted Weighted Least Squares (WLSMV) due to the violation of normally distributed data for all items according to the Mardia's test for multivariate normality, and because it provides the best option when modelling ordered data such as 5-point Likert data (Brown, 2006). The goodness-of-fit was measured using three different indices including the Comparable Fit Index (CFI) (Hu and Bentler, 1999), the Root Mean Square Error of Approximation (RMSEA) (Browne and Cudeck, 1992) and the

Standardized Root Mean Square Residuals (SRMR) (Bollen, 1989). CFI index compares the estimated model with an independent, or null, model. RMSEA index specifies to what extent the observed covariance matrix and the hypothesized covariance model are different. SRMR is an index of the average of standardized residuals between the sample covariance matrix and the hypothesized covariance model. A cut-off value for CFI greater than or equal to 0.90 and RMSEA smaller than 0.05 represent good fit. A RMSEA value falling between the range of 0.05 and 0.08 is the indicator of accepted fit. SRMR value smaller than 0.05 is the indicator of good fit while a value between 0.05 and 0.08 indicating accepted fit (Hu and Bentler, 1999; Kline, 2011).

3.4. Case study

A new advanced real-time multimodal travel app is under investigation for Copenhagen traffic management enhancement. The idea behind the system is to integrate traffic information and journey planning to include all modes of transport. From the demand side it includes multi-modal real-time information, multi-criteria route planning on the basis of time, cost, emission and caloric expenditure, multi-modal choice combinations, ridesharing opportunities, easy payment, provision on socio-technical feedback through the ability to share information with social networks, and gamification elements such as point scoring and a loyalty program. From the supply side it produces information feedback to infrastructure planning and traffic management (For mor information see PPI ITS Project, 2014).

More specifically, when it comes to its persuasive features, the new travel app is supposed to provide the users with information about CO2 emissions produced/saved by taking different travel options and the amount of calories burnt by taking active modes. It is also possible to monitor CO2 savings and calories consumption over time. Moreover, the app enables its users for registration to an environmental-friendly loyalty program: the more environmental-friendly itinerary they take, the more bonus points they earn. The bonus points can be used to get some free services (through vouchers) or public transport tickets. The collected bonus points and travel information i.e. CO2 emissions saved and calories burnt could be shared on social media.

3.5. Survey design and participants

A tailor-made web-based questionnaire was designed according to the developed behavioral framework. At the beginning of the questionnaire, participants were supported with information related to the functionalities and features of the new travel app such as multimodal travel information, incorporated persuasive strategies, bonus points, the policy of monitoring their travel behavior etc. The survey elicited the following information; 1) the likelihood of using the app measured on a 5-point Likert scale ranging from highly unlikely to highly likely 2) a set of user motives to use the app to estimate the constructs in relation to goal-framing theory 3) technophile attitude captured by individual attributes of openness and interest toward smartphone apps 4) individuals ’attitude of social trust, institutional trust and place attachment measured by the concept of community resilience and 5) a set of background variables such as socio-economic information, travel habits, travel information use habits etc. The

statements of all attitudinal variables of goal-frames, technophilia and community resilience were measured using the 5-point Likert scale ranging from strongly disagree to strongly agree.

Regarding the use intention, respondents were asked to rate the likelihood of using the app firstly, in general for their daily commute and secondly, for specific travel purposes presented in Table 3-C. The goal-framing theory suggests that the goals are likely to be situation dependent instead of stable across situations. Incorporating travel purposes in the model enabled us to examine how their effects vary according to different situations.

With respect to goal-framing theory, respondents were asked the question how using the new travel app can help/enable them to achieve different travel-related goals.

Gain goal-frame incorporated items related to functional value of the system to increase trip efficiency such as time savings for travelling and information searching, effort savings for searching information and travel cost savings. Previous studies presented trip efficiency as the most desired for the users of travel information (Chorus et al., 2007; Grotenhuis et al., 2007; Vogelsang et al., 2015).

The second goal-frame explored motives regarding the game elements of app including self-monitoring, information sharing and eco-point collection. As suggested by Muntean (2011), the application of gamification elements in non-gaming systems combines two type of motives; “on one hand using extrinsic rewards such as levels, points, badges to improve engagement while striving to raise feelings of achieving mastery, autonomy and sense of belonging”. By extension, Vassileva (2012) suggested that social motivation also plays a role, such that the social aspect of such systems might influence user behavior. For example in our case study, social motivations could be related to the possibility of competition and social comparison provided by sharing information on social media. In the field of social psychology, sociology and marketing, this is known as social value reflecting the (positive or negative) outcomes of the ownership and use of a product for one’s (self-) identity and social status. It is viewed as the product’s ability for developing social self-concept (Belk, 1988; Dittmar, 1993; Park et al., 1986; Sirgy, 1986).

Normative goal-frame investigated items related to acting appropriately in line with sustainable travel behavior such as adopting more environmentally-friendly travel alternatives and making contribution to the city CO2 emission reduction.

Technophilia was measured with statements reflecting emotional and cognitive attitudes toward using smartphone apps. The statements were inspired from the work of Seebauer et al. (2015) who investigated the attribute of technophilia in the context of online travel app. We did not consider the behavioral aspects of technophilia due to firstly, Denmark’s high smartphone penetration rate (i.e. a penetration rate of over 77% among the general population according to eMarketer’s worldwide mobile forecast) and secondly, high tendency of Danish smartphone holders to use mobile apps in daily life as shown by a recent survey in Denmark. The results showed that social networking applications (i.e. Facebook), payment applications (i.e. MobilePay) and travel planning applications (i.e. Rejseplanen and

Google Maps) are amongst the top ten popular apps which smartphone users “can least do without”, regardless of age group (Jacobsen, 2017).

We assess the last group of attitudinal variables with the concept of “Community Resilience”, originally developed by Leykin et al. (2013) for community disaster management. In our study, the notion of community resilience entails the four constructs of leadership, collective efficacy, preparedness and place attachment. The statements related to each construct were shortened and adapted to the context of transport (e.g. Leadership: “I have trust in information provided by the public transport authority”; Collective efficacy: “I can count on people in my community to travel in an environmentally sustainable manner”; Preparedness: “The transport system of my city is well-organized to be sustainable”; Place attachment: “Participating in transport-related test projects in my city is important to me”).

Individual characteristic comprised socio-economic variables, travel habits, past travel experiences and information use habits. The travel habits were asked as the frequency of traveling by car, public transport and bicycle as well as the frequency of commuting with others. The frequency was measured on a 5 Likert scale including never/rarely, less than 3 days a month, once a week, 2-3 days a week and daily. The respondents were also asked to give information about the perceived time with the modal choice and situational attributes, namely the home-work distance and home/work locations. The travel information use habits were asked as the frequency of consulting with travel information systems separately for car commute, public transport commute and bike commute. The frequency of information use was measured on a 5 Likert scale including never, rarely, sometimes, often and always.

The survey was administered from 1st April to 1st May 2017 to a sample of commuters who are older than 18 and reside or work in the greater Copenhagen area. Technical university of Denmark (DTU), Copenhagen municipality and a number of companies were selected. As for the individuals who either work or study at the university, the email addresses are accessible. Therefore, they were contacted directly. The questionnaire was distributed amongst the companies registered in the list of the Danish Bureau of Statistics. The companies with more than ten employees located in the region were included. For the sake of recruitment, more than 5,000 email invitations were sent. Copenhagen municipality also posted the questionnaire on their portal for distributing to its employees which allowed obtaining a larger sample size.

The 822 completed responses can be considered as an adequate sample size based on a rule of thumb of requiring 10 responses for each of the 41 indicators designed for our study (Nunnally et al., 1967). Table 3-A shows the sample characteristics compared to the data from the Danish National Travel Survey (TU) presented in brackets.

Variable	Categories				
Gender	Male 54% (49%)	Female 46% (51%)			
Age	Age 18-29 36% (23%)	Age 30-39 20% (21%)	Age 40-49 19% (20%)	Age 50-59 17% (16%)	Age>60 8% (20%)
Education	High school 8% (12%)	Tertiary 16% (38%)	MT further 23% (30%)	LT further 53% (20%)	
Employment	Student 25% (12%)	Part time 6% (11%)	Full time 64% (54%)	Other 5% (23%)	
Family status	Single no children 21% (30%)	Couple no children 44% (31%)	Single with children 5% (5%)	Couple with children 30% (34%)	
Commute origin	Copenhagen 35% (37%)	Suburbs 40% (33%)	Rural 25% (30%)		
Commute destination	Copenhagen 30% (44%)	Suburbs 61% (32%)	Rural 9% (24%)		
Commute distance	0-5 km 19% (39%)	5-10 km 24% (17%)	11-20 km 31% (11%)	21-30 km 10% (4%)	> 30 km 16% (29%)
Annual income before tax (DKK)	Under 200,000 26% (28%)	200,000 – 400,000 25% (37%)	400,000 – 500,000 22% (16%)	500,000 – 750,000 18% (14%)	Over 750,000 9% (5%)

Table 3-A Sample characteristics, Total sample size = 822

The sample characteristics are in line with the survey aim and scope to target adult commuters in the Greater Copenhagen Area. The sample mostly includes adults who are students or full-time employees. As can be seen, our sample is considerably different from the TU data in many categories. This was to be anticipated due to the choice of recruitment. For example, almost one fourth of the participants are students. They typically are young and therefore, in our sample the share of age group (18-29) is higher than the TU data. Correspondingly, it influenced on other categories. Another reason can be related to the recruitment of employees which implemented through companies not directly.

3.6. Results

3.6.1 Factor analysis

All the constructs of the behavioral framework including the goal-frames, technophilia and community resilience were obtained by exploratory factor analysis (EFA). EFA was employed to expose the underlying structure of the variables and investigate the theoretical constructs.

The survey data showed good internal consistency with Cronbach's alpha 0.9 and good sampling adequacy with Kaiser-Meyer-Olkin (KMO) = 0.9. The determinant of the Spearman correlations matrix equal to 2.17E-07 established the absence of multi-collinearity, and the Bartlett's test for sphericity rejected the null hypothesis of an identity correlations matrix. Principal axis factoring with oblique "promax" rotation generated the seven factors presented in Table 3.2 including three factors of the goal-frames, a factor of technophile and three factors related to the community resilience.

Table 3-B shows the generated factors, the factor loadings of the dominant items and their descriptions. The cut off of 0.3 were set to retain a set of items representing the factors. The Cronbach's alpha of each factor is also presented in brackets. All the Cronbach's alpha values are above 0.7 reflecting good internal consistency (Miller, 1995).

As shown in Table 3.2, factor F1 “Gain motives” incorporates all statements related to the goal-frame of increasing trip efficiency by using the travel app. Factor F2 “Hedonic motives” includes statements related to receiving a feedback and reward as well as gaining social approval (i.e. sharing information) which reflects users’ perceptions of the value of the game elements. Factor F3 “Normative motives” is associated with the value of using the travel app to travel more environmental friendly. Factor F4 “Technophilia” includes four items related to technology-related self-concept. Factor F5 is formed by six items related to “Leadership” and “Preparedness” constructs of the community resilience. The two constructs reflect institutional trust since they describe trust belief toward the transport planning and services provided by public institutions. F6 includes three items associated with “Collective efficacy”, obviously reflecting social trust, as the shared belief that the members of the community will effectively cooperate and work toward making the city more sustainable. F7 “Place attachment” is associated with the individual’s willingness to be updated about transport related projects and engage in the related voluntary activities in order to contribute to sustainable development of the city.

Factor name (Cronbach α)	Item	Factor loadings
F1 (0.92)	reduce my travel time	0.72
Gain motives	be on time	0.83
	pay less for daily transport	0.56
	choose my travel mode according to the departure/ arrival time	0.75
	be faster and more efficient trip	0.80
	get customized information about my preferred trips	0.77
	get cost information for each suggested trip	0.71
	get pop-ups with alternative travel modes/ routes, when there is disruption	0.67
	reduce time spend and difficulty for travel information search	0.80
	arrive on-time	0.89
F2 (0.78)	be rewarded with bonus points for eco-friendly behavior	0.42
Hedonic motives	monitor amount of calories burnt while travelling	0.65
	share information with other users	0.70
	share my saved CO2 emissions due to my eco-friendly behavior on the social media	0.83
F3 (0.81)	use more public transport	0.42
Normative motives	cycle more	0.70
	make healthier choices	0.65
	reduce the CO2 level and air pollution in Copenhagen area	0.53
F4 (0.81)	I usually like to install interesting new apps	0.86
Technophilia	I regularly use apps for payments, reservations, errands etc.	0.60
	I am enthusiastic about GPS and travel apps	0.63
	I think it is exciting to try new apps	0.82
F5 (0.81)	I have trust in information provided by the public transport authority	0.42
Institutional trust	I have faith in the authorities to lead a sustainable transport vision for my city	0.61
	In Copenhagen area, appropriate attention is given to traveler’s needs	0.74
	The residents are informed about the future vision of the city	0.43
	The transport system of my city is well-organized to be sustainable	0.83
	The current transport infrastructure and policy support a sustainable future	0.85
F6 (0.74)	I can count on people in my city to travel in an environmentally sustainable manner	0.46
Social trust	I trust that Copenhageners are willing to contribute to assure a sustainable future	0.83
	I believe that environmental concerns are shared among all the residents in my city	0.64
F7 (0.72)	Participating in transport-related test projects in my city is important to me	0.68
Place attachment	Knowing more about new travel apps in my city is important to me	0.49
	Knowing more about how to make my city sustainable is important to me	0.83
Cronbach’s alpha= 0.90, KMO = 0.90, Determinant of the Spearman correlations matrix= 2.17E-07		

Table 3-B Rotated factor matrix for attitudinal variables

As mentioned earlier, respondents were also asked to rate the likelihood of using the app for different travel purposes. EFA was implemented to reduce the items to a smaller set of underlying summary variables. The data showed good internal consistency with Cronbach's alpha 0.87, good sampling adequacy with Kaiser-Meyer-Olkin (KMO) = 0.89, the absence of multi-collinearity, and the non-existence of identity correlations matrix. Principal axis factoring with oblique "promax" rotation generated the three factors presented in Table 3-C. Similar to the attitudinal variables, the cutoff value of 0.3 for item factor loading was set. the Cronbach's Alpha values for F8 and F10 were found above 0.7 reflecting good internal consistency (Miller, 1995) while it is just acceptable when it comes to F9 since it is above the "criterion-in-use" of 0.6 (Peterson, 1994).

We named factor F8 as "Active trip" versus factor F9 as "Proactive trip". The former situation seems to stimulate individuals for travel information accusation as the response to the situation, while the latter seems to be more controlled by individuals due to e.g. lower uncertainty, not being in rush, pre-planned trip etc. Factor F10 incorporates two items related to the situation of multi-modal trip making.

Factor name (Cronbach α)	Item	Factor loadings
F8 (0.82)	Spontaneous trip making	0.66
Active trip	Trips to unfamiliar places	0.70
F9 (0.69)	Receiving short notice/info about traffic disruptions (road work, accident, congestion etc.)	0.42
Proactive trip	Long-distance trips (over 100 km)	0.57
	Wayfinding at night	0.76
F10 (0.82)	Looking for public transport schedule	0.79
Multi-modal trip	Having efficient multiple trips when switching transport mode or connection	0.68
Cronbach's alpha= 0.87, KMO = 0.89, Determinant of the Spearman correlations matrix= 0.0049		

Table 3-C Rotated factor matrix for variables related to travel purposes

It is worth mentioning that, the factor structure extracted by EFA was then used to perform SEM model. Based on the "two-indicator rule" characterized by Bollen (1989), the model is identified with at least two indicators per factor if the model has two or more factors. Particularly as the sample size is not small, the model is not susceptible to estimation problems (Kline, 2011)

3.6.2 Model estimation results

The model was estimated using the standard WLSMV estimator in M-Plus. The model comprising both structural and measurement equations fits the data reasonably well. The tested model revealed goodness-of-fit measures in terms of CFI equal to 0.926 (Browne and Cudeck, 1992) and RMSEA equal to 0.044 (Hu and Bentler, 1999). The SRMR[1] is 0.076 within the acceptable range 0f 0.05-0.08 (Hu and Bentler, 1999). Tables 3-D through 3-F show the standardized parameters estimates and critical ratios (C.R.), defined as the ratio of parameter estimate and standard error.

[1] WLSMV estimator in M-Plus does not report SRMR. We implemented the same model in R package lavaan (Rosseel, 2012), and borrowed the value of this index from the R output. Although both statistical tools provided the same model estimates, but we refer to M-Plus since it is commercial.

Table 3-D presents the estimates of the measurement equations of the CFA that agrees with the EFA displayed in Tables 3.2 and 3.3. The aim of the EFA was to identify underlying constructs for a set of measured variables when without a priori hypotheses, whereas the CFA aimed at testing how well the data fit a hypothesized, a priori, measurement model. When it comes to our data set, the factor structure was initially revealed by EFA and then was used as part of the model structure with CFA, which improves the structural validity of the proposed model.

Factor name	Item	*est.*	*C.R*
Gain motives	reduce my travel time	1.000	-
(F1)	be on time	1.193	43.18
	pay less for daily transport	0.968	33.27
	choose my travel mode according to the departure/ arrival time	1.075	37.77
	be faster and more efficient trip	1.153	42.24
	get customized information about my preferred trips	1.012	34.10
	get cost information for each suggested trip	1.05	34.26
	get pop-ups with alternative travel modes/ routes, when there is disruption	0.906	29.27
	reduce time spend and difficulty for travel information search	1.081	37.64
	arrive on-time	1.177	41.62
Hedonic motives	be rewarded with bonus points for eco-friendly behavior	1.000	-
(F2)	monitor amount of calories burnt while travelling	0.798	22.64
	share information with other users	0.812	22.55
	share my saved CO2 emissions due to my eco-friendly behavior on social media	0.861	22.89
Normative	use more public transport	1.000	-
motives	cycle more	1.112	22.95
(F3)	make healthier choices	1.252	24.13
	reduce the CO2 level and air pollution in Copenhagen area	1.279	24.76
Technophilia (F4)	I usually like to install interesting new apps	1.000	-
	I regularly use apps for payments, reservations, errands etc.	0.638	16.86
	I am enthusiastic about GPS and travel apps	0.871	25.13
	I think it is exciting to try new apps	1.102	27.37
Institutional trust	I have trust in information provided by the public transport authority	1.000	-
(F5)	I have faith in the authorities to lead a sustainable transport vision for my city	1.588	15.76
	In Copenhagen area, appropriate attention is given to traveler's needs	1.665	15.45
	The residents are informed about the future vision of the city	1.153	13.30
	The transport system of my city is well-organized to be sustainable	1.823	15.55
	The current transport infrastructure and policy support a sustainable future	1.795	15.45
Social trust	I can count on people in my city to travel in an environmentally sustainable manner	1.000	-
(F6)	I trust that Copenhageners are willing to contribute to assure a sustainable future	1.081	23.93
	I believe that environmental concerns are shared among all the residents in my city	0.88	20.50
Place attachment	Participating in transport-related test projects in my city is important to me	1.000	-
(F7)	Knowing more about new travel apps in my city is important to me	1.283	14.16
	Knowing more about how to make my city sustainable is important to me	1.204	15.17
Active trip (F8)	Spontaneous trip making	1.000	-
	Trips to unfamiliar places	1.030	41.82
Proactive trip	Receiving short notice/info about traffic disruptions	1.000	-
(F9)	Long-distance trips (over 100 km)	1.165	20.83
	Wayfinding at night	1.154	19.97
Multi-modal trip	Looking for public transport schedule	1.000	-
(F10)	Having efficient multiple trips when switching transport mode or connection	1.064	40.07

Table 3-D Estimates of the measurement equations of the latent constructs

Table 3-E shows the structural equations linking the latent variables of users' motives, technophilia and community resilience to individual characteristics.

Factor name	Variable	*est.*	*C.R.*
Gain motives	Male	-0.148	-2.66
(F1)	Age 30-39	-0.138	-1.53
	Age 40-49	-0.209	-2.31
	Age 50-59	-0.144	-1.54
	Car use: 2–3 times weekly	0.229	2.03
	Car travel time between 16-45 mins	0.178	2.93
	Transit travel time between 30-60 mins	0.162	2.66
	Travel distance less than 10 km	-0.083	-1.77
	Workplace location: Copenhagen suburb	-0.121	-1.83
	Workplace location: Copenhagen rural	-0.233	-1.87
	Information use frequency for transit travel: often and always	0.246	4.17
	Information use frequency for bike travel: often and always	-0.247	-3.48
Hedonic motives	Male	-0.215	-3.10
(F2)	Education: Bachelor	-0.156	-1.52
	Education: Master and PhD	-0.256	-2.99
	Transit use daily	-0.232	-2.22
	Travel with partner: 2–3 times weekly	0.167	1.64
Normative motives	Male	-0.173	-3.27
(F3)	Family with children	0.116	1.55
	Car use: daily	-0.169	-1.94
	Transit use: daily	-0.231	-3.04
	Transit travel time: greater than 90 mins	-0.274	-2.16
Technophilia	Age 40-49	0.304	2.31
(F4)	Information use frequency for car travel: often and always	0.210	2.34
	Information use frequency for transit travel: often and always	0.341	4.51
	Information use frequency for bike travel: often and always	0.187	2.00
Institutional trust	Age 40-49	-0.106	-1.58
(F5)	Age 50-59	-0.148	-2.47
	Age 60+	-0.236	-2.98
	Education: Master and PhD	0.091	2.04
	Transit use: daily	0.155	2.87
	Bike use: daily	0.111	1.97
	Home location: Copenhagen suburb	0.073	1.93
Social trust	Age 40-49	-0.259	-2.19
(F6)	Age 50-59	-0.186	-1.77
	Age 60+	-0.275	-1.72
Place attachment	Transit use: daily	0.220	2.74
(F7)	Travel distance less than 10 km	0.070	1.66
	Information use frequency for transit travel: often and always	0.116	2.64
	Information use frequency for bike travel: often and always	0.188	3.17

Table 3-E Linkage between individual characteristics and the users' motives, technophilia and community resilience constructs

Table 3-F shows the structural equations according to the conceptual model. Direct effect, total effect and corresponding hypothesis are shown in this table.

		Direct effect		*Total effect*		Supported
Dependent/mediator variables	Explanatory variables	*est.*	*C.R.*	*est.*	*C.R.*	hypothesis
Social trust (F6)	Institutional trust (F5)	0.918	11.891	0.918	11.891	H5
Gain motives (F1)	Place attachment (F7)	0.753	11.896	0.753	11.896	H4
	Technophilia (F4)	0.306	11.345	0.306	11.345	H2
Hedonic motives (F2)	Institutional trust (F5)	-	-	0.343	7.108	H4
	Social trust (F6)	0.374	8.582	0.374	8.582	H4
	Place attachment (F7)	1.036	12.580	1.036	12.580	H4
	Technophilia (F4)	0.215	6.378	0.215	6.378	H2
Normative motives (F3)	Institutional trust (F5)	-0.113	-1.710	0.106	1.963	H4
	Social trust (F6)	0.239	6.149	0.239	6.149	H4
	Place attachment (F7)	1.137	12.015	1.137	12.015	H4
	Technophilia (F4)	0.158	5.954	0.158	5.954	H2
Adoption intention	Institutional trust (F5)	-	-	0.028	1.817	-
	Social trust (F6)	-	-	0.063	3.797	-
	Place attachment (F7)	-	-	0.406	7.555	-
	Gain motives (F1)	0.143	3.063	0.143	3.063	H1
	Normative motives (F3)	0.263	4.760	0.263	4.760	H1
	Technophilia (F4)	0.239	7.712	0.324	10.427	H3
Active trip making (F8)	Institutional trust (F5)	-	-	0.056	3.054	-
	Social trust (F6)	-	-	0.078	4.460	-
	Place attachment (F7)	-	-	0.536	9.777	-
	Gain motives (F1)	0.264	7.151	0.338	7.413	H1
	Hedonic motives (F2)	0.120	3.215	0.120	3.215	H1
	Normative motives (F3)	-	-	0.138	4.638	H1
	Technophilia (F4)	0.129	4.488	0.405	13.136	H3
	Adoption intention	0.525	20.738	0.525	20.738	-
Proactive trip making (F9)	Institutional trust (F5)	-	-	0.088	4.737	-
	Social trust (F6)	-	-	0.106	6.110	-
	Place attachment (F7)	-	-	0.451	9.736	-
	Gain motives (F1)	0.120	3.621	0.162	4.502	H1
	Hedonic motives (F2)	0.233	7.104	0.233	7.104	H1
	Normative motives (F3)	-	-	0.077	4.381	H1
	Technophilia (F4)	0.143	5.543	0.325	11.411	H3
	Adoption intention	0.294	11.855	0.294	11.855	-
Multi-modal trip (F10)	Institutional trust (F5)	-	-	0.029	1.787	-
	Social trust (F6)	-	-	0.065	3.790	-
	Place attachment (F7)	-	-	0.579	9.416	-
	Gain motives (F1)	0.298	7.117	0.358	7.401	H1
	Normative motives (F3)	0.160	3.108	0.272	4.851	H1
	Technophilia (F4)	0.127	4.122	0.382	11.963	H3
	Adoption intention	0.426	16.470	0.426	16.470	-
Correlation patterns	Active trip - Proactive trip	0.190	12.123	-	-	-
	Active trip - Multi-modal trip	0.263	16.399	-	-	-
	Proactive trip - Multi-modal trip	0.180	11.086	-	-	-

Table 3-F Linkage between the goal-frames, community resilience, technophilia and the use intention

The relation between the goal-frames, technophilia, community resilience constructs and individual characteristics

According to Table 3-E, the latent constructs are significantly related to demographics, home and work place locations, commute characteristics, travel and information use habits, indicating the relationship between socio-ecological system and individual attitudes and the values developed by using the new app.

The gain motives, the value of using the app for improving trip efficiency, are stronger for respondents who (i) are female, (ii) are at younger ages (iii) use car 2–3 times weekly (iv) car traveling takes between 16-45 mins, (v) transit traveling takes between 30-60 mins and, (vi) are frequent users of travel information sources when they travel by public transport. "Gain motives" are linked negatively to shorter travel distance, workplace being in rural and suburban rather than Copenhagen, possibly due to lower perceived problems with congestion, as well as people who use more frequently information sources for bike travel.

The motives related to the game elements i.e. "Hedonic motives" are positively linked to respondents who (i) are female, and (ii) travel with partner 2–3 times weekly whereas they are negatively associated with (i) habitual daily transit users and, (ii) higher educated people. Previous studies showed that social motivations for using online communication tools are stronger for female (e.g. Valkenburg and Peter, 2007; Zillien and Hargittai, 2009). The observed difference regarding the level of education can be explained by the findings of Van Deursen et al. (2015) showing that online gaming is more appealing for lower educated people and they use the Internet more for gaming activities than higher educated.

The normative motives are stronger for respondents who (i) are female and, (ii) have children possibly due to the need to serve as role models. They are negatively linked to (i) habitual daily car and transit users, (ii) habitual daily transit users and, (ii) respondents who transit traveling takes more than 90 mins. Previous studies asserted that females are more likely to adopt environment-friendly travel while habitual travelers are less likely to consider other alternatives and accordingly change their travel behavior (e.g., Clark et al., 2016; López-Mosquera et al., 2015; Prillwitz and Barr, 2011; Yang et al., 2013)

Technophile attitude is stronger for people at middle age as well as frequent users of travel information sources. Prior studies showed that the availability and use of information technologies (Clark et al., 2015; Goulias et al., 2004), previous positive experience with travel information and favorable attitude toward their usefulness (Farag and Lyons, 2010; Xu et al., 2010) play an important role in individuals affinity to such technologies and use of ATIS.

When it comes to the constructs of community resilience, "Institutional trust" is stronger for respondents who (i) are at younger age, and (ii) are higher educated (iii) habitual daily transit users, (iv) habitual daily cyclists and, (v) their home located in suburban rather than Copenhagen. "Social trust" is perceived stronger for younger adults and "Place attachment" is positively linked to (i) habitual daily transit users, (ii) shorter travel distance and, (iii) frequent users of travel information sources for commuting by bike and public transport.

The relation between the goal-frames, technophile attitude, community resilience and the use intention

In order to avoid a complex path diagram of the model structure, we split it into four separate diagrams presented in Figures 3-3 through 3-6. Figure 3-3 displays the relationship between adoption intention and situational use plus correlation pattern. Figure 3-4 displays the strength of the relationship between the three goal-frames, adoption intention and situational use intention. Figure 3-5 shows how technophilia influences goal-directed behavior and use intention and finally, Figure 3-6 displays the relationship between trust ecology, place attachment and goal-frames.

As we expected, Figure 3-3 confirms that adoption intention relates positively to the situational use of the app, meaning that individuals with higher tendency to adopt the travel app are more likely to use it for different travel purposes.

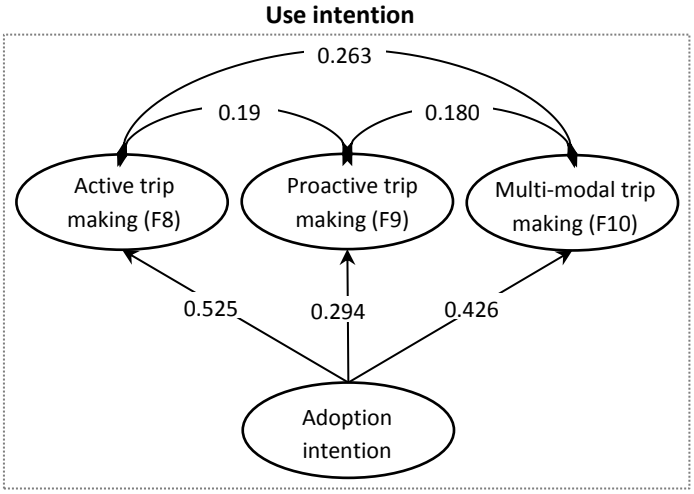


Figure 3-3 Path diagram of adoption intention and situational use intentions

In Figure 3-4, the model structure supported hypothesis H1 that the three distinct goal-frames relate to use intention and their influence are situation dependent.

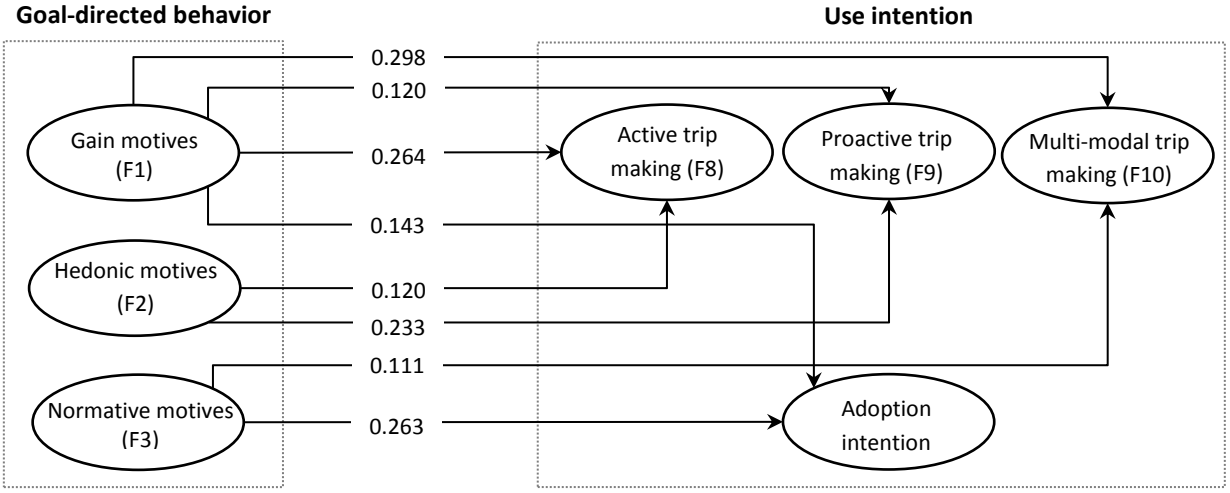


Figure 3-4 Path diagram of goal-frames and use intention

It suggests that acceptance and use of the VTBC-based travel app is associated not only with gain motives but also with psychological motives such as social interaction, enjoyment, normative etc. The specific results show that the gain goal-frame is positively related to adoption intention and situational use, indicating functional usefulness as the fundamental value in the use of VTBC-based travel app. In line with goal-framing theory, trip efficiency improvement appears to be constantly activated and dominate its use. The hedonic and normative goals also frame and guide the use intention; however individuals are drawn to the corresponding motives depending on the situation/purpose. The results have important practical implications. Since gain motives play a significant role in adoption behavior, the usefulness of the system for time savings (i.e. travelling and information searching), effort savings (i.e. searching information) and travel cost savings should thus be stressed throughout the process of system development, business design and marketing. Furthermore, the value of emotional enjoyment, social interaction and green travel behavior which is triggered by persuasive strategies, are appealing to users of VTBC-based travel app and should therefore be emphasized in marketing materials.

The model structure presented in Figure 3-5, confirmed hypotheses H2 and H3 that use intention and users' goal-frames correlate positively with stronger technophile.

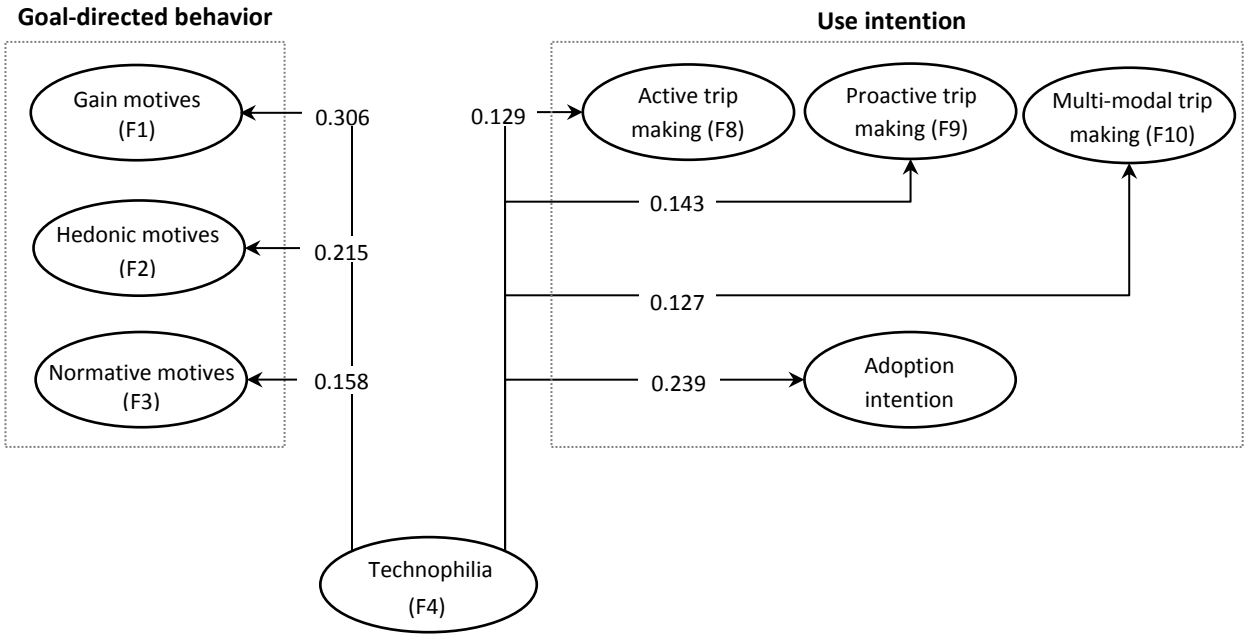


Figure 3-5 Path diagram of technophilia, goal-frames and use intention

It suggests those people with higher affinity to information technology on one hand, perceive the values of VTBC-based travel app as more important, and on the other hand, are more likely to use the app, clearly characterizing technophiles as the key target group of this new generation of travel information systems. Edison and Geissler (2003) argues that understanding individual differences in terms of technological affinity/aversion could be helpful for the design and promotion of high-tech products such as ATIS by "informing the design of user interfaces and functionalities", "enabling technophile early adopters for persuasive advertising", and "improving customer segmentation".

According to Figure 3-6, the model structure also confirmed hypotheses H4 (i.e. indirect effect of community resilience constructs on use intention) and H5 (i.e. the causal effect of institutional trust on social trust).

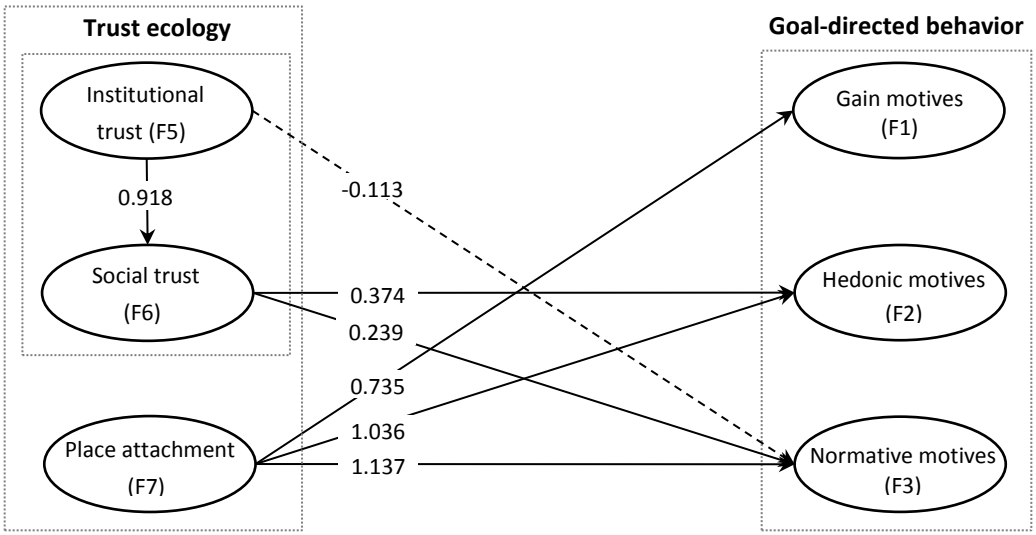


Figure 3-6 Path diagram of trust ecology, place attachment and goal-directed behavior

"Institutional trust" is positively linked to "social trust"; in line with institutional performance theories suggesting trust appears "from the top down" saying that "it is effective government that enables social trust and association membership to appear…. good government is the most essential feature for generating citizen trust and a civil society capable of supporting civic participation" (Allum et al., 2010).

"Institutional trust" negatively associated with the normative goal-frame. Those individuals with higher trust in institutions appear to perceive less important the value of the travel information system to promote environmentally friendly travel behavior. They are less concerned with sustainability-oriented mobility behavior, which the system adoption is envisioned to foster in the city. The negative association between trust and pro-environmental behavior where collective action is needed also reported by recent studies (e.g., Carattini et al., 2015; Volland, 2017). Diffusion of responsibility effect (Darley and Latane, 1968) could be considered as one explanation for this finding. Diffusion of responsibility can happen in multiple actor environments when each actor may believe that others either responsible for taking action or have already done so. In our study, individuals with higher trust feel less responsible for making their own contribution since they may believe that the institutions/organizations are potentially responsible to develop the city in a sustainable manner. There is little pressure for them to take action as they neglect their own extra involvement and responsibility. According to Leary and Forsyth (1987), they may rely extensively on experts (e.g., transport planners) or leaders (e.g., transport policy makers) and accordingly, the feeling of responsibility diffuses to them. Prior studies provided empirical evidence for this effect on environmental behavior in relation to pro-social behavior (e.g., Anker and Feeley, 2011; Santarius and Soland, 2018; Soland, 2013).

People with stronger social trust perceive more important the hedonic and normative goal-frames indicating that the social, hedonic and normative motives are important drivers for their attraction and engagement. Collective efficacy as a social identity variable appears to develop a sense of collaborative engagement by the formations of goals intended to satisfy higher order needs such as sense of belonging, social approval and green travel promotion.

Higher "Place attachment" relates positively to the three distinct goal-frames, suggesting that those individuals with higher feeling of place attachment put more value and importance on the functional, social, hedonic and environmental attributes of the new travel app. For this group, their affective bonds with the city drive their opinion of the new information system and develop a positive evaluation of its value to improve the city's quality of life.

The social dynamic behind the system and its influence on users' attitude and behavior indicate the importance of public engagement to achieve the goals of the system implementation. Luederitz et al. (2015) view urban areas as human environment systems in which participation is an important constituent to ensure sustainable urban design and planning. Banister (2008) argues that public participation in sustainable mobility planning contributes to promoting socially responsible behavior in a more effective way since it could develop sustainable values and facilitate the desired attitude and behavior change amongst citizens. Furthermore, public acceptability of sustainable solutions such as ATIS could be triggered by public engagement. The public must be engaged at the start instead of toward the end of the planning process i.e. a shift from "design-defend-implement" to "discuss-design-implement" (Bickerstaff et al., 2002; Leyden et al., 2017). In the field of transport, a number of systematic frameworks to embed public engagement established by previous studies (e.g., Banister, 2008; Cascetta et al., 2015; de Luca, 2014; O'Faircheallaigh, 2010; Bickerstaff et al., 2002)

In summary, these results suggest that there is an association among technophile attitude, users' motives, trust ecology, place attachment and use intention of VTBC-based travel app. Based on these data, it can be inferred that an individual's motives toward the use of the travel app are highly relevant to the individual's general attitudes of social trust, institutional trust and place attachment. Furthermore, stronger technophile attitude influence positively both users motives and use intention. Behavioral intention to use the travel app is positively affected by functional and psychological motives; however their effects are situation based.

3.7. Limitations and future direction

While our study provides important insights, the evaluation of the study in light of its limitations is noteworthy. Firstly, this study did not include a population representative sample which is mainly related to the data collection and distribution method. Data collection through online survey restricts the target population to a pool of Internet users as respondents. Future study needs to address this issue by incorporating other methods such as telephone or face-to-face interviews.

Secondly, the data for this study were collected from Danish travelers. It would be useful to replicate this study using other countries' travelers in order to better attain the robustness of the results. It is recommended to examine the hypothesized relations in cross-cultural settings. This would improve the current understanding of VTBC-based travel app adoption in a multicultural context owing to possible cultural differences in perceptions.

Thirdly, it is important to investigate barrier effects as reasons against adoption of VTBC-based travel app along with the reasons for its adoption. A recent study by Claudy et al. (2015) shows that the influence of barriers on innovation adoption behavior is almost twice as strong as those of adoption factors. In this context, risk barrier (e.g., information privacy concern) and usage barrier (e.g., complexity of the idea and use, time consuming, and unsatisfied expectations about the gamification elements) are two examples. We encourage future studies to explore the factors that lead to the user resistance.

Lastly, during the survey administration, the new travel app was not yet deployed. Hence, the focus of this study was on the phase of before adoption. Additional research is required to employ a longitude design to investigate post-adoption behavior. It is essential to appraise the long-term effects of such technologies on travel behavior modification.

3.8. Conclusion

The motivation for this study reflects the evolving needs of motivating sustainable urban mobility and the development of persuasive technologies, as well as from questions and gaps revealed from the literature in travel information and users behavior. Specially, we identified that there is a lack of knowledge about how individuals are motivated to accept and adopt VTBC-based travel apps as well as the challenges related to users' attraction. The prevalence of smartphone use, the rapid proliferation of mobile devices sensors and social networks popularity for sharing information have created new market for collaborative travel apps, and brings up significant questions about how travelers behave in this market.

This study provides empirical evidence that user attraction and engagement is associated with the travel app ability to satisfy functional and psychological human needs. The results show the use intention of the VTBC-based travel app is not exclusively guided by their functional utility for improving trip efficiency. But also, it depends on their ability to satisfy emotional needs (i.e. by triggering feelings of enjoyment, sense of belonging and social identification) as well as develop normative values.

The specific results show that, the higher level of gain motives were related to higher level of the use intentions, i.e. both adoption intention and situational use, whereas when it comes to hedonic and normative motives, this positive relation is conditional on travel purpose. Therefore, the loyal users of the app could be catheterized by being functionally motivated specifying the importance of the functional values of the system to attract and engage future users.

The results also show that technophiles are an important target group of VBTC-based travel app. They can play a significant role in promoting the use of this new generation of travel information system, thus contributing to a rapid increase in demand. However, the system attributes and functionalities should be designed aligned to the needs of both groups of technophiles and technophobes. For example, as suggested by Seebauer et al., (2015), on one hand, the entry threshold for unwilling users should be lowered (e.g. easy and understandable feature design) and on the other hand, tech-lovers should be appealed (e.g. providing the possibility of participatory design).

The results support that place attachment and trust ecology influence on users' attitude and behavior. It indicates that public engagement is important in ensuring the success of the system implementation. It is essential to develop a meaningful dialogue between decision makers and the public as to create its public acceptance. The public dialogue should be rest on – and accompanied by – a robust communication strategy to understand citizens travel needs and expectations, clarify the need for change in their travel behavior and underscore the importance of their contribution.

The study has also provided authorities and app designers with an understanding of different user groups, the aspects of VTBC-based travel app they value and accordingly their motivations and barriers for use.

Acknowledgement

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4. Factors Driving the Adoption of Mobility-Management Travel App: A Bayesian Structural Equation Modelling Analysis

Based on the accepted paper below:

Mehdizadeh, A., Kaplan, S., Silva, J. D. A. E., Nielsen, O. A. & Pereira, C. P (2019). Factors driving the adoption of mobility-management travel app: A Bayesian structural equation modelling analysis. Accepted for *the Transportation Research Board (TRB), 98th Annual Meeting, Washington D.C., USA, January 13-17, 2019)*

ABSTRACT

The increasing complexity and mobility demand of transport services strains the transportation system especially in urban areas with limited possibilities to build new infrastructure. The solution to this challenge requires changes in travel behavior. One of the proposed means to induce such change is mobility-management travel apps. However, understanding the motivators underlying individuals' travel intentions is essential to design and evaluate their effectiveness. This paper aims to pinpoint and understand the drivers that influence individual travel decisions when using such apps. The analytical framework relies on goal-framing theory in which individual's motives to use the app are grouped into three overarching goals namely, 1) gain, 2) hedonic and 3) normative goals. Furthermore, technophilia, social trust and place attachment are incorporated in the framework as to better explain user-sided heterogeneity. The case-study focuses on a hypothetical travel information system in Lisbon (Portugal) through a technology-use preference survey to 227 travelers. Bayesian Structural equation models revealed that the choice drivers are specific to individual users and depends on wide ranging factors that go above traditional economic and socio-demographic methods. The study revealed that firstly, trip efficiency improvement, enjoyment, social interaction and eco-friendly travel promotion are among those motives explaining the adoption intention. Secondly, there are different intentions among individuals depending on the users' motives. Third, technophilia exerts a positive influence on adoption intention. Fourth, the social dynamic behind the system, influence positively the use of the travel app.

Keywords: Travel app; Travel information; Behavior change; Mobility management; Technophilia

4.1. Introduction

The use of information-based mobility management strategies has been suggested already in the beginning of the millennium but only gained momentum recently. A range of advanced traveler information systems (ATIS) for mobility-management are presented by Gärling et al. (2004). They include navigation applications (apps) that notify the driver regarding route alternatives and alerts, sharing information regarding joint trips, real-time information regarding public transport, voluntary travel behavior change programs (VTBC) - also known as individualized marketing, and travel role-modelling through social networks. These information-based strategies, besides their low-cost to decision makers and wide availability to the general public, are potentially powerful from the behavioral perspective. Problem awareness by giving information affects perceived responsibility, behavioral control and social norms that in turn affect behavioral intentions and actions (Bamberg et al., 2011; Eriksson et al., 2006). They encourage informed decisions, thus encouraging people to make a rational choice based on costs and benefits (Steg and Vlek, 2009), and make "the right choice for the right reasons" thus satisfying higher-order emotional needs of self-actualization, important for long-term behavioral shifts (te Brömmelstroet, 2014).

Traditional VTBC solutions require person-based interaction, either by phone or home interviews, which is inherently expensive and may induce biases stemming from social interaction and communication. ATIS assisted VTBC offers opportunities to reduce the costs associated with the need for human-based interaction. While most travel apps are still based on the traditional view of digitized traffic information, the newest generation of ATIS include user-based alerts, prescriptive advices (e.g., route alternatives and changes), reflective memory (e.g., the ability to save past and future trips and locations), and persuasive strategies (i.e., carbon emission scores, interaction with social networks, and loyalty points and rewards) (Brazil et al., 2013; Brazil and Caulfield, 2013; Yujuico, 2015). ATIS replacing human interaction with digital schemes are currently under development offering, among other possibilities, opportunities for communication and collaboration across users, information sharing and social networking. Field experiments provide evidence that these new features are important in influencing users to change their travel behavior (Andersson et al., 2018; Koo et al., 2015; Nakashima et al., 2017; Sedera et al., 2017).

The application of VTBC-based travel app is an active area of research. Ubigreen, MatkaHupi, Peacox, SuperHub, Tripzoom and IPET are some examples of the mobile app which are still under development (Meloni and Teulada, 2015). The underpinning concept is based on Fogg's framework (Fogg, 2003) in which system design is persuasive and explicitly attempts to change attitudes or behaviors or both. This is achieved by raising awareness of individual choices, patterns, and the consequences of activities. Persuasive technologies monitor human activities in relation to resource usage, and provide information to the user for the purpose of motivating behavioral change (Brynjarsdottir et al., 2012).

Tailoring the travel solutions that support individual needs and expectations can possibly lead to a powerful potential travel shift toward eco-friendly solutions. There is a wide agreement that satisfying user needs are fundamental for the design, implementation and dissemination of mobility-management

travel apps aimed at encouraging VTBC (Andersson et al., 2018; Gabrielli et al., 2014; Grotenhuis et al., 2007; Meloni and Teulada, 2015; Wang et al., 2016). While the concept of needs is long-standing in empirical psychology for studying motivation, with the shift toward cognitive theories this concept was largely replaced by goal-related efficacy (Deci and Ryan, 2000). This study contributes to the body-of-knowledge by offering to explore goal-framing theory (Lindenberg, 2006) a motivator for the intentions to use mobility-management travel app.

This study focuses on exploring the motivation to use the new real-time multi-modal travel app for Lisbon, as ATIS for digital mobility-management assistance. The new multi-modal travel app, a VTBC-based ATIS, is a multi-faceted mobile app including both travel information and persuasive strategies such as health and environmental feedback, tailoring travel options, self-monitoring, tunneling users toward green behavior, social networking, nudging and gamification elements. Due to the collaborative feature of this new generation of travel apps, a critical mass is essential for market penetration and use (Dickinson et al., 2015). There are three behavioral change elements that may induce target behavior through using ATIS: motivation, ability and triggers for behavioral change (Meloni and Teulada, 2015). Our study aims to explore these aspects through the lens of social psychology and social science. In that, a better grasp of the motivators and barriers for ATIS market penetration will aid authorities and private entrepreneurs to design effective and appealing ATIS, eventually translating into to wider potential of VTBC. How ATIS have an influence is highly dependent on how users interface with the system. Noticeably, this process is not distinctly technological, but has a social dimension, which forces a socio-technical evaluation (Dickinson et al., 2015).

4.2. Theoretical framework

4.2.1 Goal-framing theory

In an environmental context, goal-framing theory argues that, in every situation individuals want to achieve a goal which incorporates certain kinds of motives. Motives are separated into three overarching categories of goals (i.e. “focal goal” or “goal-frame”) according to core desires and needs they satisfy. The goals, which are likely to be situation dependent instead of stable across situations, govern or frame individuals information processing and their action. Thus, they influence individuals’ attitude, feelings and actions. The three categories of goals are hedonic goal-frame “to feel better right now”, gain goal-frame “to guard and improve one's resources”, and normative goal-frame “to act appropriately” (Lindenberg, 2006).

While simple navigation apps are mostly driven by their functional value, the use of a VTBC-based travel app is likely to embrace hedonic motives as well as the aspects of social responsibility and personal morality. This study investigates different motives in the framework of goal-framing theory as backbone for user attraction and engagement. We hypothesized that there are three different goal-frames which explain the use of VTBC-based travel app.

4.2.2 Technophilia

Consumer attitudes and psychological factors can be critical for the marketing of innovative technologies which affect their success. With the purpose of analyzing these factors, we investigated the role of technophilia which refers to "a person's openness, interest in and competence with (innovative) technologies". Technophile attitude comprises three components namely, affective (e.g. satisfaction, anxiety or enjoyment), behavioral (e.g., experience or frequency of use), and cognitive (e.g., technology self-efficacy) (Seebauer et al., 2015). Prior literature supports the direct effect of technophile attitudes on innovation adoption behavior. For example, the potential target groups for electric bike (Wolf and Seebauer, 2014), electric vehicles (Hackbarth and Madlener, 2016) and advanced travel information systems (Seebauer et al., 2015) are among people who are technophiles with an affinity to innovation and technology. Therefore, we hypothesized that technophilia has a positive relation with the use of VTBC-based travel app.

4.2.3 Social trust and place attachment

One of the main limitations of persuasive technologies is to focus on targeting specific behaviors and choices of individuals instead of proposing more collective approaches, which address the relevant communities that could have a higher impact on adoption (Brynjarsdottir et al., 2012; Gabrielli et al., 2014). With exclusive focus on individuals and their responsibility to use the system, the promotion of sustainable travel behavior might not be achieved due to disregarding the social dynamics and the need for change at other scales beyond the individuals (Hekler et al., 2013; Strengers, 2011).

To enrich the behavioral framework as well as address the limitation, we incorporated the notion of 'social trust' in to the model which is the kind of trust that individuals place on each other. Beside values, the importance of trust and its role as motivator for goal-directed behavior were highlighted by prior studies since trust reinforces peoples' engaging behavior i.e. acceptability and public involvement (Hsu et al., 2012; Steg et al., 2015). Individuals with more social trust may have more of a tendency to pursue the common good of society, promoting participation in collective action. It is mainly due to the fact that they tend to believe other members will also be concerned with and collaborate to protect the common good (Stern and Baird, 2015).

Place attachment is another factor often assumed to affect residents' attitude and behavior in relation to local issues and collaborative actions. Place attachment refers to an affective bond that people establish with specific place and it is widely viewed as an important part of human identity. Considering people's emotional connections with the city may provide a better understanding of their motivations, reactions to, and participation in local community-based action (Manzo and Perkins, 2006; Scannell and Gifford, 2013).

As suggested by Ajzen and Fishbein (1980), general attitudes do not have a direct effect on specific behaviors but they are indirect determinants through situation-specific beliefs, operating via their impact on generating situation-specific cognition. In this paper, social trust and place attachment are

general attitudes, thus we investigate their effects on intention to use VTBC-based travel app mediated by the goal-frames.

4.3. Conceptual model

Figure 4-1 describes the conceptual behavioral framework. Based on the above literature review, the proposed framework led to the following research hypotheses;

H1: There are three different groups of motives regarding the use of VTBC-based travel app which explain its adoption.

H2: Technophilia relates positively to adoption intention.

H3: Social trust and place attachment have a positive effect on use intention, mediated by goal-frames.

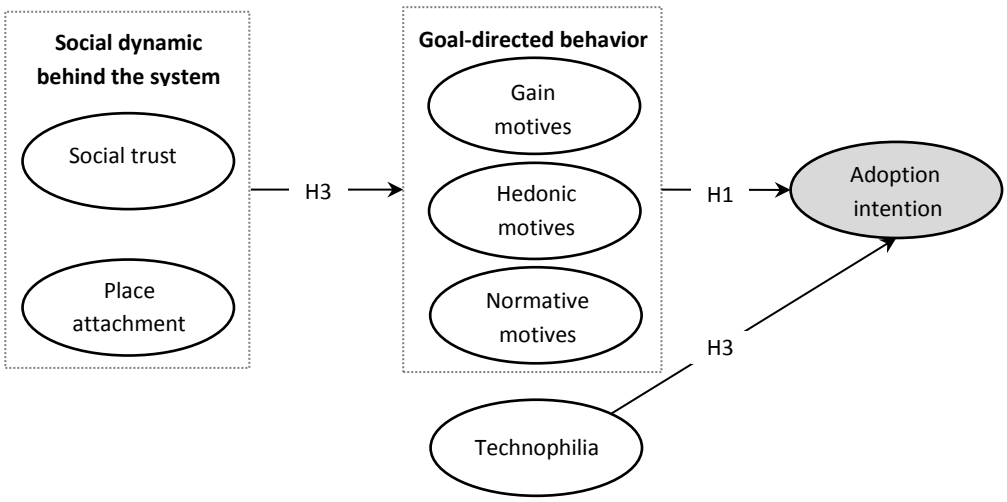

Figure 4-1 Conceptual model on motivations to use the app

4.4. Modeling approach

The behavioral model structure representing the research hypotheses was investigated by applying Bayesian structural equation model (BSEM). Bayesian methods are better equipped to model data with small sample sizes (McNeish, 2016).

4.4.1 Bayesian structural equation model

The model contained three sets of equations presented below;

$$x = \Lambda\xi + \varepsilon \quad \text{and} \quad \varepsilon \sim N(0, \Psi_\varepsilon) \tag{1}$$

$$\xi = BS + \omega \quad \text{and} \quad \omega \sim N(0, \Psi_\omega) \tag{2}$$

$$y = \Gamma\xi + \delta \quad \text{and} \quad \delta \sim N(0, \sigma^2) \tag{3}$$

Eq. (1) links the measurement indicators to the latent variables. x is a vector of indicators describing a random vector of latent variable ξ; Λ is a matrix of the loading coefficients obtained from the

regressions of x on ξ; and ε represents random vectors of the measurement errors which is distributed as $N(0, \Psi_\varepsilon)$. If ξ is exogenous (hereafter presented by ξ^*), then the latent construct is assumed to be distributed as $N(0, \Phi)$ which Φ is factor covariance matrix.

Eq. (2) links the (endogenous) latent constructs ξ to individual characteristics. S is a vector of the respondents' individual characteristics (e.g. socio-economic, travel habit etc.) and B are the parameters representing the regression relations. The error term is ω which is a vector following a normal distribution with covariance matrix Ψ_ω.

Eq. (3) represents regression relations between the latent variables and the dependent variable y. In this equation, y is the likelihood level of using the new information system in accordance with the behavioral framework. Γ is a matrix of the coefficients obtained from the regressions of y on ξ.

In Bayesian analysis, it is needed to specify a full likelihood and prior distributions for the parameters. In this study, the full likelihood function, including the latent variables, has the following form:

$$\mathcal{L}(y, x, \xi, S|\Theta) = \prod_{i=1}^{n} \{N(x_i|\Lambda\xi_i, \Psi_\varepsilon) \times N(y_i|\Gamma\xi_i, \sigma^2) \times N(\xi_i|BS_i, \Psi_\omega) \times N(\xi_i^*|0, \Phi)\} \quad (4)$$

Where n is the number of observations and $\Theta = (\lambda, \gamma, \beta, \psi_\varepsilon, \psi_\omega, \phi, \sigma^2)$ is the vector of the model parameters. To complete the model specification, it is needed to choose priors for each of the parameters. There are three main types of prior probability distributions namely, informative, uninformative, and weakly informative that vary in their degree of (un)certainty about the model parameters. In order to avoid the influence of priors on the estimations, uninformative priors are specified. The joint posterior distribution for the parameters and latent variables is computed, following Bayes' rule, as

$$P(\Theta, \xi|y, x, S) = \frac{\mathcal{L}(y, x, \xi, S|\Theta)P(\Theta)}{\int \mathcal{L}(y, x, \xi, S|\Theta)P(\Theta)d\xi d\Theta} \quad (5)$$

Eq. (5) is the complete data likelihood multiplied by the prior and divided by the marginal likelihood. Calculating the marginal likelihood is a difficult computational problem, since it requires computing very high-dimensional integrals. To address this issue, Markov chain Monte Carlo (MCMC) methods can be used to sample from the joint posterior distribution. "Due to the conditionally normal linear structure of the SEM and to the choice of conditionally priors for the parameters, MCMC computation can proceed through a straightforward Gibbs sampling algorithm" (Lee, 2007).

4.4.2 BSEM with cross-loadings and residual correlations

Consider Eq. (1) which is the measurement part of the model. The corresponding covariance structure is presented as

$$\mathrm{Cov}(x) = \Lambda\Phi\Lambda^{T} + \Psi_\varepsilon \quad (6)$$

The residual covariance matrix in Eq. (6) is usually assumed to be diagonal; however, some residuals might be correlated because of the omission of some minor factors. In BSEM without cross-loadings, zeros are specified in Λ for the factor indicators that are hypothesized to not be influenced by certain factors. Having a zero loading can be considered as a prior distribution with both mean and variance equal to zero. Whereas, in BSEM with correlated residuals, the assumption of diagonal residual covariance matrix does not hold. In this study, we consider a prior with mean zero and a normal distribution with small variance for cross-loadings (not main loadings). The choice of informative prior $\lambda \sim N(0,0.005)$ generate a prior where 95% lies between -0.14 and +0.14. A loading of -/+0.14 is regarded a minor loading, suggesting that this prior basically provides the cross loading near to zero, but not precisely zero (Muthén and Asparouhov, 2012).

4.4.3 Model fit and model comparison in Bayesian context

Model fit in the Bayesian context relates to assessing the predictive accuracy of a model, and is referred to as posterior predictive checking (Gelman et al., 2004; Muthén and Asparouhov, 2012). Posterior predictive checks are, "simulating replicated data under the fitted model and then comparing these to the observed data" (Gelman et al., 2004). Therefore, posterior predictive is used to "look for systematic discrepancies between real and simulated data"(Gelman et al., 2004). Any discrepancy between the generated data and the real data suggests possible model misfit. In this context, posterior predictive p-value (ppp) is an indicator for the model fit which is computed by chi-square discrepancy function. The ppp value around 0.50 is the indicator of a well-fitting model.

Deviance Information Criterion (DIC) is a Bayesian generalization of the Maximum Likelihood AIC and BIC. The DIC compares candidate models with respect to their ability to predict new data of the same kind. The DIC protects against overfitting by penalizing models with larger numbers of effective parameters. When comparing different candidate models for the same data, smaller values of DIC suggest better predictive ability similar to BIC (Gelman et al., 2004).

4.5. Case study

This study is a part of PhD project aiming at investigating to what extend a new advanced real-time multimodal travel planner could promote eco-friendly travel behavior in the City of Copenhagen. The case study is also extended to Lisbon Metropolitan Area (LMA), which is the focus of this paper. The new travel app is expected to include features such as multi-modal real-time information, multi-criteria route planning on the basis of time and cost, multi-modal choice combinations, ridesharing opportunities and easy payment. In order to induce behavioral change, persuasive strategies are also considered by the system.

The new travel app is supposed to provide the users with information about CO2 emissions produced/saved by taking different travel options and the amount of calories burnt by taking active modes. It is also possible to monitor CO2 savings and calories consumption over time. Moreover, the app enables its users for registration to an environmental-friendly loyalty program: the more environmental-friendly itinerary they take, the more bonus points they earn. The bonus points can be

used to get some free services (through vouchers) or public transport tickets. The collected bonus points and travel information i.e. CO2 emissions saved and calories burnt could be shared on social media.

4.6. Survey design and participants

A tailor-made web-based questionnaire was designed according to the developed behavioral framework. At the beginning of the questionnaire, participants were supported with information related to the functionalities and features of the new travel app such as multimodal travel information, incorporated persuasive strategies, bonus points, the policy of monitoring their travel behavior etc.

The survey elicited the following information; 1) the likelihood of using the app measured on a 5-point Likert scale ranging from highly unlikely to highly likely 2) a set of user motives to use the app to estimate the constructs in relation to goal-framing theory 3) technophile attitudes captured by individual attribute of openness and interest toward smartphone application 4) individuals 'attitudes of social trust and place attachment and 5) a set of background variables such as socio-economic information, travel habits, travel information use habits etc. The statements of all attitudinal variables (i.e. the three goal-frames, technophilia, place attachment and social trust) were measured using the 5-point Likert scale ranging from strongly disagree to strongly agree.

With respect to goal-framing theory, respondents were asked the question how using the new travel app can help/enable them to achieve different travel-related goals. Gain goal-frame incorporated items related to functional value of the system to increase trip efficiency such as time savings for travelling and information searching as well as effort savings for searching information. Trip efficiency was found as the most desired for the users of travel information (Grotenhuis et al., 2007; Vogelsang et al., 2015).

The second goal-frame explored motives regarding the game elements of app including self-monitoring, information sharing and eco-point collection. As suggested by Muntean (Muntean, 2011), the application of game elements in non-gaming systems combines two type of motives; "on one hand using extrinsic rewards such as levels, points, badges to improve engagement while striving to raise feelings of achieving mastery, autonomy and sense of belonging". By extension, Vassileva (Vassileva, 2012) suggested that social motivation also plays a role, such that the social aspect of such systems might influence user behavior. In our case study, social motivations could be related to the possibility of competition and social comparison provided by sharing information on social media.

Normative goal-frame investigated items related to acting appropriately in line with sustainable travel behavior such as adopting environmentally-friendly travel alternatives and making contribution to the city CO2 emission reduction.

Technophilia was measured with statements reflecting emotional and cognitive attitudes toward using smartphone applications. The statements were inspired from the work of Seebauer et al. (2015) who investigated the attribute of technophilia in the context of online travel planners.

The statements related to social trust and place attachment were borrowed from the concept of community resilience, originally developed by Leykin et al.(2013) for community disaster management. The statements were shortened and adapted to the context of transport.

Individual characteristic comprised socio-economic variables, travel habits, past travel experiences and information use habits. The travel habits were asked as the frequency of traveling by car, public transport and active modes. The frequency was measured on a 5 Likert scale including never/rarely, less than 3 days a month, once a week, 2-3 days a week and daily. The respondents were also asked to give information about the perceived time with the modal choice and situational attributes, namely the home-work distance and home/work locations. The travel information use habits were asked as the frequency of consulting with travel information systems separately for car, public transport and active modes. The frequency of information use was measured on a 5 Likert scale including never, rarely, sometimes, often and always.

The survey was administered from 1st May to 1st June 2017 to a sample of commuters who are older than 18 and reside or work in the LMA. The survey yielded 227complete responses. Table 4-A describes the sample socio-economic characteristics. The sample characteristics are in line with the survey aim and scope to target commuters in the LMA. The sample is gender balanced and includes adults either full time employees or university students.

Variable	Categories				
Gender	Male 55%	Female 45%			
Age	Age 18-29 25%	Age 30-39 20%	Age 40-49 25%	Age 50-59 15%	Age>60 15%
Education	High school 1%	Tertiary 13%	Bachelor 44%	Graduate 42%	
Employment	Student 22%	Part time 2%	Full time 64%	Other 12%	
Family status	Single no children 23%	Couple no children 45%	Single with children 5%	Couple with children 27%	
Commute origin	Center 52%	Suburbs 31%	Rural/Outer suburbs 17%		
Commute destination	Center 80%	Suburbs 8%	Rural/Outer suburbs 12%		
Commute distance	0-5 km 25%	5-10 km 21%	11-20 km 27%	21-30 km 16%	> 30 km 11%
Income group	Low 19%	Medium 34%	High 32%	No-answer 15%	

Table 4-A Sample characteristics, Total sample size = 227

4.7. Result

4.7.1 Factor analysis

All the constructs of the behavioral framework including the goal-frames, technophile, social trust and place attachment were first revealed by exploratory factor analysis. The survey data showed good

internal consistency with Cronbach's alpha 0.88 and good sampling adequacy with Kaiser-Meyer-Olkin (KMO) = 0.83. The determinant of the Spearman correlations matrix equal to 1.58E-05 established the absence of multi-collinearity, and the Bartlett's test for sphericity rejected the null hypothesis of an identity correlations matrix. Principal axis factoring with oblique "promax" rotation generated the six factors of the behavioral framework. Tables 4.2 show the generated factors, the factor loadings of the dominant items and their descriptions. The cut off of 0.4 were set to retain a set of items representing the factors. The Cronbach's alpha of each factor is also presented in brackets. All the Cronbach's alphas are above 0.7 reflecting good internal consistency.

As shown in Table 4-B, factor F1 "Gain motives" incorporates all statements related to the gain motive of increasing trip efficiency by using the travel app. Factor F2 "Hedonic motives" includes statements related to receiving a feedback and reward as well as gaining social approval (i.e. sharing information) which reflects users' perceptions of the value of the game elements. Factor F3 "Normative motives" is associated with the value of using the travel planner to travel more environmental friendly. Factor F4 "Technophilia" includes four items related to technology-related self-concept. F6 includes three items reflecting "Social trust" i.e. the shared belief that the members of the community will effectively cooperate and work toward making the city more sustainable. F7 "Place attachment" is associated with the individual's willingness to be updated about transport related projects and engage in the related voluntary activities in order to contribute to sustainable development of the city.

Factor name (Cronbach α)		Item	Factor loadings
F1 (0.91)	GM1	reduce my travel time	0.71
Gain	GM 2	be on time	0.94
motives	GM 3	be faster and more efficient trip	0.89
	GM 4	get pop-ups with alternative travel modes/ routes, when there is disruption	0.63
	GM 5	reduce time spend and difficulty for travel information search	0.77
	GM 6	arrive on-time	0.90
F2 (0.76)	HM1	be rewarded with bonus points for eco-friendly behavior	0.78
Hedonic motives	HM 2	monitor amount of calories burnt while travelling	0.73
	HM 3	share information with other users	0.42
	HM 4	share my saved CO2 due to my eco-friendly behavior on social media	0.64
F3 (0.79)	NM1	cycle more	0.85
Normative	NM2	make healthier choices	0.79
motives	NM3	reduce the CO2 level and air pollution in Copenhagen area	0.51
F4 (0.80)	TPH1	I usually like to install interesting new apps	0.73
Technophilia	TPH2	I regularly use apps for payments, reservations, errands etc.	0.72
	TPH3	I am enthusiastic about GPS and travel apps	0.72
	TPH4	I think it is exciting to try new apps	0.67
F5 (0.74)	ST1	I can count on people in city to travel in an environmentally sustainable manner	0.44
Social trust	ST2	I trust that Lisboners are willing to contribute to assure a sustainable future	0.90
	ST3	I believe that environmental concerns are shared among all the residents in city	0.83
F6 (0.84)	PA1	Participating in transport-related test projects in my city is important to me	0.86
Place attachment	PA2	Knowing more about new travel apps in my city is important to me	0.86
	PA3	Knowing more about how to make my city sustainable is important to me	0.69

Table 4-B Rotated factor matrix for attitudinal variables

4.7.2 Model estimation results

The model was estimated using the BAYES estimator in MPlus due to the relatively small sample size (Muthén and Muthén, 2012). To evaluate model quality, ppp for model assessment, and DIC for model choice were used. We implemented two BSEMs in Mplus i.e. with and without cross-loadings. The BSEM with zero cross loadings (Model 1) had the PPP value of zero and DIC equals to 13305. The BSEM with cross loadings and residual covariance (Model 2) had the PPP of 0.262 and the DIC value of 13092.

Model 2 is preferred since it provides an acceptable PPP and a lower DIC. As suggested by (Muthén and Asparouhov, 2012), a ppp value greater than 0.05 is a reasonable indicator of acceptable fit. The remaining tables are based on the estimate of Model 2.

Table 4-C displays the estimates of the measurement equations of the latent variables from Model 2.

	Indicator	Gain motives	Hedonic motives	Normative motives	Technophilia	Social trust	Place attachment
Gain motives	GM1	**1.000**	-0.009	0.063	0.071	-0.004	0.002
	GM 2	**1.154***	-0.016	0.048	0.013	-0.042	-0.047
	GM 3	**1.073***	0.001	0.063	-0.022	0.017	-0.024
	GM 4	**0.789***	0.067	0.024	0.090	0.010	0.068
	GM 5	**0.939***	0.102	0.015	-0.042	0.012	0.011
	GM 6	**1.076***	0.053	-0.028	-0.048	0.003	-0.016
Hedonic motives	HM1	0.047	**1.000**	0.008	0.028	-0.058	0.060
	HM 2	0.082	**1.027***	0.070	0.091	0.000	-0.060
	HM 3	0.207*	**0.659***	-0.011	0.013	0.049	0.019
	HM 4	-0.032	**0.819***	0.095	0.006	0.020	0.010
Normative motives	NM1	0.004	0.024	**1.000**	0.024	-0.006	-0.032
	NM2	0.018	-0.026	**0.862***	0.048	-0.021	0.023
	NM3	0.235*	0.118*	**0.528***	-0.023	0.051	0.020
Technophilia	TPH1	-0.023	0.018	0.015	**1.000**	-0.012	0.021
	TPH2	-0.015	0.038	-0.006	**0.931***	0.030	0.015
	TPH3	0.067	-0.001	0.054	**1.005***	0.007	0.051
	TPH4	0.068	0.065	0.063	**0.925***	0.042	0.022
Social trust	ST1	0.005	0.032	0.019	0.025	**1.000**	-0.003
	ST2	-0.039	-0.067	-0.007	0.010	**2.100***	0.008
	ST3	-0.057	-0.019	-0.060	-0.005	**2.057***	-0.009
Place attachment	PA1	-0.068	-0.045	0.020	0.001	-0.023	**1.000**
	PA2	0.053	-0.062	-0.055	0.134*	0.000	**0.987***
	PA3	-0.040	0.071	0.029	-0.053	0.024	**0.813***

NOTE:

Factor loadings in bold indicate major loadings

Major loadings were freely estimated using uninformative priors(i.e. the default priors in Mplus)

Asterisks indicate 95% credibility interval does not contain zero

Table 4-C Estimates of the measurement equations

Table 4-D shows the structural equations linking the latent variables of goal-frames and technophilia to individual and commute characteristics. Furthermore, it shows the structural equations according to the behavioral model.

Part(1): Linking the goal-frames and technophilia to individual and commute characteristics				
	Estimate	Posterior S.D.	95% PPI	90% PPI
Gain motives (F1)				
Male	-0.168	0.098	(-0.364) - (0.023)	**(-0.330) - (-0.006)**
Car use frequency	0.072	0.033	**(0.006) - (0.138)**	-
Transit use frequency	0.059	0.034	**(0.008) - (0.126)**	-
Travel Info use frequency for car	0.147	0.044	**(0.062) - (0.237)**	-
Travel Info use frequency for transit	0.088	0.046	**(0.001) - (0.179)**	-
Hedonic motives (F2)				
Male	-0.259	0.101	**(-0.464) - (-0.067)**	-
Normative motives (F3)				
Active mode use frequency	0.107	0.038	**(0.033) - (0.181)**	-
Travel Info use frequency for active mode	0.409	0.096	**(0.226) - (0.602)**	-
Income: Low	0.284	0.168	(-0.044) - (0.616)	**(0.007) - (0.056)**
Income: Medium	0.234	0.131	(-0.023) - (0.493)	**(0.017) - (0.449)**
Technophilia (F4)				
Male	0.216	0.104	**(0.017) - (0.428)**	-
Travel Info use frequency for car	0.214	0.046	**(0.128) - (0.309)**	-
Travel Info use frequency for transit	0.100	0.044	**(0.016) - (0.190)**	-
Part(2): Linking the goal-frames, technophilia, social trust, place attachment and adoption intention				
	Estimate	Posterior S.D.	95% PPI	90% PPI
Gain motives (F1)				
Social Trust (F5)	0.361	0.176	**(0.078) - (0.773)**	**-**
Place attachment (F6)	0.188	0.075	**(0.043) - (0.340)**	-
Hedonic motives (F2)				
Social Trust (F5)	0.405	0.189	**(0.095) - (0.837)**	**-**
Place attachment (F6)	0.284	0.087	**(0.121) - (0.462)**	-
Normative motives (F3)				
Social Trust (F5)	0.523	0.224	**(0.174) - (1.050)**	**-**
Place attachment (F6)	0.309	0.095	**(0.122) - (0.495)**	-
Adoption intention				
Gain motives (F1)	0.383	0.096	**(0.201) - (0.577)**	-
Hedonic motives (F2)	-0.135	0.074	**(-0.281) - (-0.008)**	**-**
Normative motives (F3)	0.099	0.061	(-0.020) - (0.220)	**(0.001) - (0.200)**
Technophilia (F4)	0.251	0.098	**(0.063) - (0.447)**	-
NOTE:				
PPI stands for posterior probability interval				
PPI values in bold indicate the corresponding credibility interval does not contain zero				

Table 4-D Estimates of the structural equations

The relation between the goal-frames, technophilia and individual characteristics

According to Table 4-D, part (1), the latent constructs are significantly related to demographics, travel and information use habits, indicating their influence on individual attitudes and values developed by using the new app.

The value of using the app for improving trip efficiency i.e. “Gain motives” are stronger for respondents who (i) are female, (ii) commute more frequently by car and public transport (iii) and consult more

frequently with travel information sources when commuting by car and public transport. The results indicate that there is a strong relation between gain motives and the functional aspects of the app.

The motives related to the game elements i.e. “Hedonic motives” are negatively linked to male indicating a gender difference in the perceived value of the app. A previous study shows that social motivations for using online communication tools are stronger for female (Valkenburg and Peter, 2007). Possibly, because the game attributes of the app mostly trigger social interaction (i.e. receiving feedback, being rewarded and information sharing), they are perceived more important for females as a new communication channel.

“Normative motives” are stronger for respondents who (i) commute more frequently with active modes, (ii) consult more frequently with travel information sources for commuting by active modes and, (iii) belong to low and middle income groups rather than high income. People who use active modes are driven by normative goal-frame and thus are more prone to use the app on the same basis.

Technophile attitude is stronger for frequent users of travel information sources. Prior studies showed that the availability and use of information technologies (Goulias et al., 2004), previous positive experience with travel information and favorable attitude toward their usefulness (Farag and Lyons, 2010; Xu et al., 2010) play an important role in individuals affinity to such technologies and use of ATIS.

The relation between the goal-frames, technophilia, social trust, place attachment and adoption intention

As shown in Table 4-D, part (2) and the path diagram of Figure 4-2, the model structure supported hypothesis H1 that the three distinct goal-frames relate to use intention. It suggests that acceptance and use of the VTBC-based travel app is associated not only with the functional value of the system but also with psychological needs such as social interaction, enjoyment, normative etc.

The specific results show that the “Gain motives” is positively related to adoption intention indicating functional usefulness as the fundamental value in adopting VTBC-based travel app. In line with goal-framing theory, the adoption intention is dominated by the gain goal of trip efficiency improvement since it has the highest positive coefficient. “Normative motives” and “Hedonic motives”, as the background goal-frames, interfere with the gain goal and therefore affect adoption behavior. More specifically, the normative motives appear to promote the gain goal-frame while the hedonic motives conflict with the dominant goal-frame. These results have important practical implications. Since gain motives play a significant role in adoption behavior, the usefulness of the system for time savings (i.e. travelling and information searching) and effort savings (i.e. searching information) should thus be stressed throughout the process of system development, business design and marketing. Furthermore, the value of green travel behavior which is triggered by persuasive strategies, are appealing to users of VTBC-based travel app and should therefore be emphasized in marketing materials.

Figure 4-2 also confirmed hypothesis H2 that adoption intention and users’ goal-frames correlate positively with a stronger technophile attitude. It suggests those people with higher affinity to

information technology are more likely to use the app, clearly characterizing technophiles as the key target group of this new generation of travel information systems. Understanding individual differences in terms of technological affinity/aversion could be helpful for the design and promotion of high-tech products such as ATIS by "informing the design of user interfaces and functionalities", "enabling technophile early adopters for persuasive advertising", and "improving customer segmentation" (Edison and Geissler, 2003).

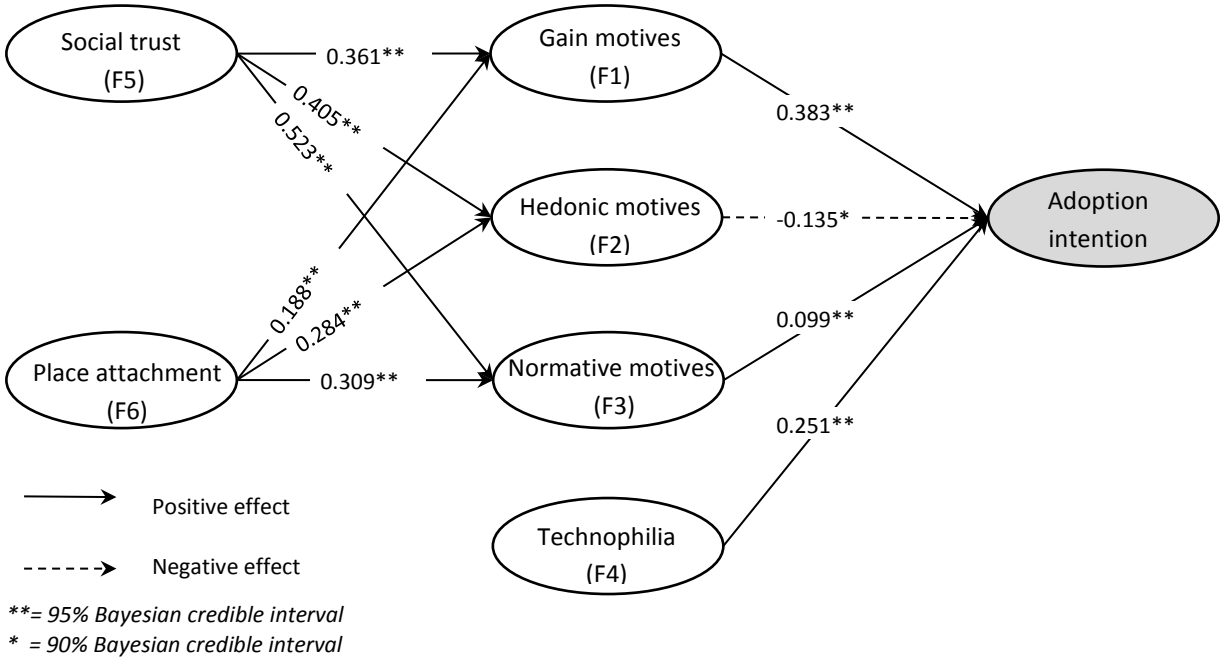

Figure 4-2 Model structure

According to Figure 4-2, the model structure also confirmed hypotheses H3 i.e. indirect positive effect of place attachment and social trust constructs on the adoption intention. People with stronger social trust perceive the values of the new travel app as more relevant. For this group of people, in addition to trip efficiency improvement, the social, hedonic and normative motives are important drivers for their attraction and engagement. Collective efficacy as a social identity variable appears to develop a sense of collaborative engagement by the formations of goals intended to satisfy higher order needs such as sense of belonging, social approval and green travel promotion. Higher "Place attachment" relates positively to the three distinct goal-frames, suggesting that those individuals with stronger feelings of place attachment put more value and importance on the functional, social, hedonic and environmental attributes of the new travel app. For this group, their affective bonds with the city drive their opinion of the new information system and develop a positive evaluation of its value to improve the city's quality of life.

The social dynamic behind the system and its influence on users' attitude and behavior indicate the importance of public engagement to achieve the goals of the system implementation. Urban areas are human environment systems in which participation is a key component to ensure sustainable urban planning. Public participation in sustainable mobility planning contributes to more efficient sustainable

behavior promotion since it may facilitate changing people's attitudes and behaviors and encouraging sustainable values. Furthermore, public acceptability of sustainable solutions such as ATIS could be triggered by public engagement (Banister, 2008). The public must be engaged at the start rather than toward the end of the planning process i.e. a shift from "design-defend-implement" to "discuss-design-implement" (Leyden et al., 2017).

4.8. Conclusion

The prevalence of smartphone use, the rise in mobile devices sensors and social media popularity for sharing information has influenced decision makers into thinking that collaborative travel app could be a key to promote behavior change toward eco-friendly travel modes. However, the literature review revealed a lack of understanding about how individuals are motivated to accept and adopt VBTC-based travel app as well as the challenges related to users' attraction.

Our study examined to what extent gain, hedonic and normative motives together translate into the adoption behavior. The study provides empirical evidence that higher levels of gain and normative motives were both related to higher level of the app adoption while it is opposite for hedonic motives. Therefore, the potential users of the app could be catheterized by being both functionally and normatively motivated not hedonically motivated. The strength of these effects indicates that gain motives dominate the adoption intention indicating the importance of the functional values of the system for users' attraction and engagement.

The results also show that technophiles are an important target group of VBTC-based travel app. They can play a significant role in promoting the use of this new generation of travel information system, thus contributing to a rapid increase in demand. However, the system attributes and functionalities should be designed aligned to the needs of both groups of technophiles and technophobes. On one hand, the entry threshold for unwilling users should be lowered (e.g. easy and understandable feature design) and on the other hand, tech-lovers should be appealed (e.g. providing the possibility of participatory design).

The results support that place attachment and social trust influence on users' attitude and behavior. It indicates that public engagement is important in ensuring the success of the system implementation. It is essential to develop a meaningful dialogue between decision makers and the public as to create its public acceptance. The public dialogue should be rest on – and accompanied by – a robust communication strategy to understand citizens travel needs and expectations, clarify the need for change in their travel behavior and underscore the importance of their contribution.

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Author contribution statement

The authors confirm contribution to the paper as follows: study conception, theoretical framework and survey design: A. Mehdizadeh D, S. Kaplan; data collection: A. Mehdizadeh D, J. Abreu e Silva; analysis and interpretation of results: A. Mehdizadeh D, S. Kaplan, J. Abreu e Silva, O.A. Nielsen, and F.C. Pereira; draft manuscript preparation: A. Mehdizadeh D, S. Kaplan, J. Abreu e Silva. All authors reviewed the results and approved the final version of the manuscript.

5. Discovering Causal Structure from Observations: The Relationships between Technophile Attitude, Users Value and Use Intention of Mobility Management Travel App

Based on a working paper: To be submitted

5.1. Introduction

Statistical association analysis such as correlation analysis has been a main method to identify useful relationships from observational data. However, associations are not necessarily causal since they may be either accidental, or spurious or conditional. Discovering causal structure from data is important due to the insights provided by causal relationships. Some well-acknowledged methods from machine learning to discover causality rest on probabilistic graphical modeling (PGM) (Heckerman et al., 1995; Pearl, 2009). The structure of PGMs is a directed acyclic graph (DAG), with its nodes representing random variables and edges indicating dependence relationships between the variables. A DAG presents the full joint probability of the variables (Edwards, 2000). There are two main approaches for learning the causal structure, namely constraint-based techniques and score-based techniques. The constraint-based approach (Cooper, 1997; Pearl, 2009; Silverstein et al., 2000) uses conditional independence tests to learn the dependence structure of the data. In this context, the PC algorithm (Spirtes et al., 2000) is the most commonly used. The PC algorithm has two stages. It starts with a complete, undirected graph and removes recursively edges as conditional relations are identified i.e. the skeleton establishment. Then, it determines the orientation to form an equivalence class of DAGs. It is important to note that DAGs which induce the same sets of conditional independence relations are called Markov equivalent. The score-based algorithms (Heckerman et al., 1995) search for all possible DAGs whilst using a scoring function to measure the fit of each DAG to the data. The DAG that best fits the data will be chosen. Some well-known search methods such as hill-climbing algorithm or greedy search are applied to optimize a score, for example the Bayesian information criterion (BIC) or the Akaike information criterion (AIC). Tsamardinos et al. (2006) presented a hybrid constraint/score-based algorithm, called Max-Min Hill-Climbing (MMHC) for discovering causal structure. The algorithm combines the ideas of both approaches. It starts with a constraint-based algorithm to find the skeleton and then performs a greedy hill-climbing search to orient the edges.

This study investigates the applicability of causal discovery methods to establish the associations between the constructs of a theoretical framework for the study of intention to use the new mobility-management travel app in Copenhagen. In other words, we want study the possibility of inference of an interpretable causal structure directly from data. The prospective for mobility-management travel apps to stimulate sustainable mobility rests not only on the original and proper employment of the behavior

change strategies, but also on "explicitly grounding it on established theoretical constructs from behavioral theories". The theoretical foundation is important because it positively and significantly influences the effectiveness of the system (Andersson et al., 2018; Arnott et al., 2014; Webb et al., 2010). However, as noted by Sunio and Schmöcker (2017) and Klein et al. (2014), there is a gap in current knowledge regarding the study of mobility-management travel apps with support in behavioral theories, which should be explored further. This study addresses this gap by a social cognitive theory-based examination. However, compared to conventional method in technology adoption research, this study adopts a reverse approach in which the associations between theoretical constructs are explored by the MMHC algorithm.

5.2. Theoretical framework

This study employs Bandura's triadic reciprocal determinism (TRD) to explain user adoption behavior of the new travel app. TRD is often used as a conceptual and theoretical framework in studies using social cognitive theory (SCT) for understanding, predicting and changing behavior. TRD represents human behavior as a result of the interaction between personal/cognitive factors, behavior and the environment. Therefore, human behavior could be a depiction of the cognition of themselves and the environment around them (Bandura, 1986, 1978). Figure 5-1 displays the model of triadic reciprocal determinism.

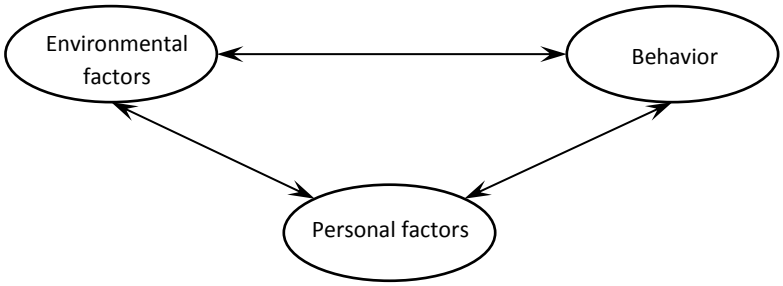

Figure 5-1 Bandura's Triadic Reciprocal Determinism

Zhu et al. (2017) conceptualized a behavioral model, based on TRD, to investigate the factors influencing the use of ridesharing mobile app. In their proposed framework, personal factors and the environment were presented by technology self-efficacy and perceived value respectively. Figure 5-2 shows the proposed conceptual model in which the solid and dotted lines denote, respectively, before-adoption and post-adoption.

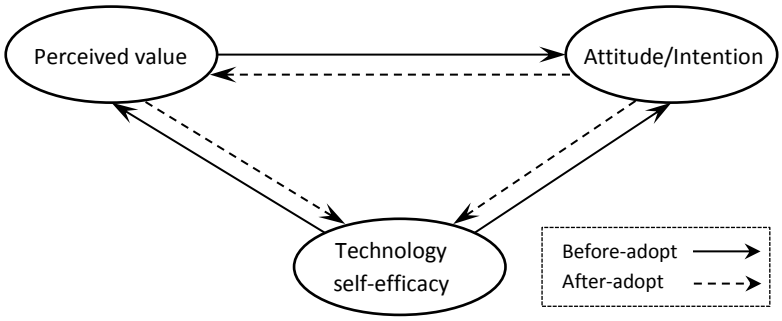

Figure 5-2 Self-efficacy based value adoption model (Source: Zhu et al., 2017)

The present study investigates to what extent the conceptual model suggested by Zhu et al. (2017), before-adoption phase, can be learned from data. We used the collected data for the study of "Use Intention of Mobility-Management Travel App: The Role of Users Goals, Technophile Attitude and Community Resilience", Chapter 3. Three groups of user's motives (i.e. gain, hedonic and normative), technophilia and adoption intention were incorporated in order to discover the causal relationships between the constructs.

Recall from Chapter 3, regarding the adoption intention, respondents were asked to rate the likelihood of using the travel app for their daily commute, on a 5-point Likert scale ranging from highly unlikely to highly likely. With respect to the user's motives, respondents were asked the question how using the new travel app can help/enable them to satisfy different travel-related needs. Technophilia was measured with statements reflecting emotional and cognitive attitudes toward using smartphone apps. The statements of the three groups of user's motives and technophilia were measured using the 5-point Likert scale ranging from strongly disagree to strongly agree.

The constructs of user's motives and technophilia were obtained by exploratory factor analysis (EFA). Table 5-A displays the constructs and their corresponding items.

Construct name	Item
Gain motives	reduce my travel time
	be on time
	pay less for daily transport
	choose my travel mode according to the departure/ arrival time
	be faster and more efficient trip
	get customized information about my preferred trips
	get cost information for each suggested trip
	get pop-ups with alternative travel modes/ routes, when there is disruption
	reduce time spend and difficulty for travel information search
	arrive on-time
Hedonic motives	be rewarded with bonus points for eco-friendly behavior
	monitor amount of calories burnt while travelling
	share information with other users
	share my saved CO2 emissions due to my eco-friendly behavior on the social media
Normative motives	use more public transport
	cycle more
	make healthier choices
	reduce the CO2 level and air pollution in Copenhagen area
Technophilia	I usually like to install interesting new apps
	I regularly use apps for payments, reservations, errands etc.
	I am enthusiastic about GPS and travel apps
	I think it is exciting to try new apps

Table 5-A Attitudinal constructs and their items

5.3. Methodological approach

This study considers probability distributions of the random vector $V = \{X_1, \ldots, X_5\}$, consisting of the four attitudinal variables and the adoption intention, that may be represented by a DAG. It is worth mentioning that, the four latent variables (i.e. three groups of user's motives plus technophilia) were estimated based on SEM and afterwards included in the data set. The random vector follows a multivariate normal distribution and the variables have a causal structure which is to be discovered

from the data using the Max-Min Hill-Climbing (MMHC) algorithm (Tsamardinos et al., 2006). The MMHC is a hybrid algorithm and based on two steps. The first step, called restrict, learns the undirected skeleton by a constraint-based technique, namely the Max-Min Parents and Children (MMPC). The MMPC algorithm constructs the skeleton by executing a statistical conditional independence test between variables (e.g., G^2 statistical test; Spirtes et al., 2000). If there is a subset S such that $X \perp Y|S$, two random variables X and Y are conditionally independent given S, then the skeleton does not add the edge between X and Y. If two random variables X and Y are conditionally dependent for any subset S, then the edge between X and Y is added in the skeleton. The second step, called maximize, is the edge orientation using a greedy hill-climbing algorithm within the restricted search space of the skeleton. Therefore, the search in the MMHC algorithm to find the optimal DAG is constrained to only consider adding/deleting/reversing an edge remained after the restrict step.

5.4. Results

The structure was learned using the function of mmhc in the bnlearn package in R (Scutari, 2010). It is worth mentioning that the first step of the MMHC algorithm used significance test $p<0.05$, and the second step used BIC scores. The selected model is presented in Figure 5-3. All the edges are directed, meaning that there is no Markov equivalent.

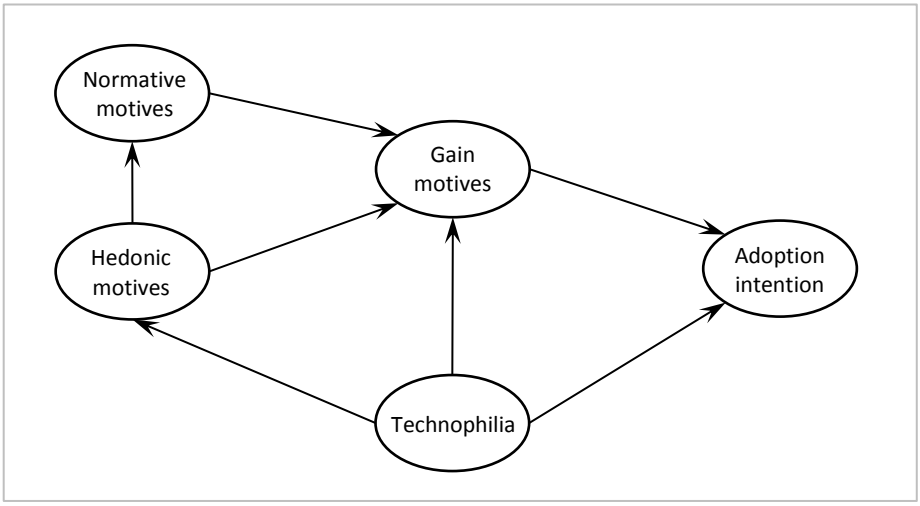

Figure 5-3 Estimated causal structure

5.5. Discussion and conclusion

The estimated causal structure shows that the two constructs of gain motives and technophilia have a causal effect on adoption intention. Likewise, there is a causal relationship from technophilia to both gain and hedonic motives. These findings agree with the self-efficacy based value adoption model developed by Zhu et al. (2017); however, no dependency between technophilia and normative motives was established. In line with the findings of the prior chapters, it once more highlights the importance of functional value of the system, as well as technology self-concept, as two important variables for adoption intention. Furthermore, the results indicate the effect of technophile attitude on developing both gain and hedonic motives as discussed in Chapter 3.

The causal structure shows hierarchical associations between the three groups of user's motive. They can be explained by the "frustration-regression" principle according to Alderfer's (1969) ERG (Existence, Relatedness and Growth) theory meaning that a higher level need remains unfulfilled, a person may regress to lower level needs that appear easier to satisfy. More specifically, hedonic and normative values of the system are probably not perceived as appealing as its functional values. There might be issues in accomplishing the higher-order needs; hence users regress to gain motives. For example, they might believe that travel information systems, even this new generation, should continue to serve their traditional role, which is contributing to trip efficiency improvement. The complexity of idea might be another cause encouraging its adoption through developing the functional values.

We are aware of the potential challenges of this method. For example, by increasing the number of variables, discovery of causal relationships from the observation might be challenging, due to e.g., Markov equivalent classes. This challenge is even more critical for similar studies aiming at interpreting the discovered structure based on a behavior theory. As shown in Chapters 2 through 4, general attitudes do not have a direct effect on specific behaviors, but it is indirectly determinant through situation-specific beliefs and attitude (Ajzen and Fishbein, 1980). Learning structure directly from data may add undesirable associations between variables, which are not interpretable. To deal with, prior beliefs can be implemented in causal discovery algorithms by taking constrains on edges i.e., present, absent, fixed direction etc.

To conclude, this study shows the capability of causal discovery methods to learn the causal structure of theoretical framework, and accordingly interpret established associations. In Chapter 3, Lindenberg's goal-framing theory was incorporated into the framework while here Alderfer's theory of human needs appears to be well fitted. For the next step, it is of interest to replace the goal-framing theory with the ERG model in Chapter 3, and compare the goodness-of-fit between the two SEMs.

6. Conclusions

This chapter summarizes the research motivation and key contributions of the dissertation, as well as discusses limitations and directions for future research. Sections 6.1 reviews the research motivation and objectives pointed out in Chapter 1. Sections 6.2 and 6.3 present the key contributions and policy implications respectively. Finally, the limitations and future research directions are discussed in Section 6.4.

6.1. Motivation and dissertation structure

The motivation of this PhD study derives from the evolving needs of encouraging sustainable urban mobility and the development of advanced traveler information systems (ATIS), as well as from the problems and gaps revealed from the literature in travel information and users behavior. Specially, we identified that there is a lack of knowledge about how individuals are motivated to accept and adopt ATIS assisted voluntary travel behavior change (VTBC), as well as the challenges related to users' attraction and engagement in ATIS.

The prevalence of smartphone use, the rapid development in mobile devices sensors and social networks popularity for sharing information, all together, have created a new market for mobility-management travel apps, the new generation of ATIS, and brings up significant questions about how travelers behave in the market. Understanding travelers' behavior in this emerging market is important since it can influence a wide range of stakeholders such as App developers, travel information service providers, transport policy makers and transport operators, accommodate to design effective and appealing ATIS, and eventually contribute to a shift toward sustainable mobility behavior. The success of mobility-management travel apps and their efficacy for motivating sustainable travel behavior highly depends on understanding the underlying mechanisms and processes of human behavior change. It indicates the importance of anchoring behavioral theories and models of behavioral change to the study of VTBC-based travel apps; however, it is not well explored by prior studies.

Given the gap in current knowledge, the present study is motivated to explain the users' behavior of mobility-management travel apps with support in behavioral theories. This problem is addressed in Chapters 2 through 5 by developing theoretical frameworks that serve as modelling backbones. With the help of behavioral theories, this PhD dissertation takes wide-ranging factors into account for explaining the adoption behavior. This study reveals contributing factors for the development of appealing ATIS from users' point of view in order to address their needs and expectations. In this context, the ERG model of human needs (Alderfer, 1969), goal-framing theory (Lindenberg, 2006; Lindenberg and Steg, 2007), and triadic reciprocal determinism (Bandura, 1986, 1978) are employed in order to accomplish a well-founded research in behavioral theories. The objectives addressed by this PhD study can be summarized as follows:

Chapter 2 investigates contributing factors for the use of persuasive functions of a mobility-management travel app, and determines their effects on the registration for environmental loyalty

program. Chapter 2 characterizes both drivers (e.g., functional and psychological user needs) and barriers (e.g., information privacy concern) that influence individual travel decisions when using such apps. To capture a wider set of motivators and better explain the heterogeneity of users' behavior, environmental attitude is also included.

Chapters 3 and 4 provide new insights, based on two case studies from Demark and Portugal, to explain the underlying mechanisms of mobility-management travel app users' behavior by considering different groups of user's motives, as well as technology self-concept as an important personal factor in technology adoption research. Chapters 3 and 4 also capture the social dynamic behind the information system in order to avoid the sole focus on users as isolated individuals, narrowing the vision of sustainability, and disregarding the influence of the social environment on human behavior.

In line with the overall aim of the dissertation, Chapter 5 investigates how different constructs of the proposed theoretical framework associate with adoption behavior. However, compared to the work carried out in previous chapters, Chapter 5 adopts a reverse approach to explore the relationships. More specifically, instead of testing models that are conceptually derived beforehand and evaluating how well the theory fits the collected data, the objective is to learn causal structure directly from the data and then examine the application of behavior theories to explain the discovered structure. To some extent, this approach can be considered as a validation method; however, the approach is new and needs to be further explored.

This PhD dissertation tests empirically the theoretical frameworks developed in this research using three different technology preference datasets collected specifically for this purpose. Chapters 2, 3 and 4 describe the survey design and distribution method enabling the collection of rich dataset and large enough sample size for data analysis. The quality of the survey protocol is ensured by the use of preliminary focus groups and a pilot survey. Structural equation modeling (SEM) (Chapters 2 and 3), Bayesian structural equation modeling (BSEM) (Chapter 4) and Max-Min Hill-Climbing (MMHC) for discovering causal structure (Chapter 5) are the employed quantitative techniques for data analysis.

6.2. Key contributions

From the literature review presented in this dissertation (mainly in Chapters 2 and 3), this PhD study extends existing knowledge in the field by tracing the application of persuasive technologies in travel behavior studies, outlining important criteria for designing effective interventions to change travel behavior, integrating perspectives and findings from ICT and consumer behavior literature, and providing a structure to indicate both existing achievements and gaps. The main contribution of this dissertation is new insights into the influence of psychological factors on adoption behavior of mobility-management travel apps with special emphasis on the application of behavior theories.

The contribution of Chapter 2 is the detailed analysis of the influence of psychological factors on the use intention toward persuasive functions of travel app by unifying both drivers and barriers in a single framework. The decision-making framework relies on Alderfer's (1969) ERG (Existence-Relatedness-

Growth) theory of human needs. Therefore, the use intention is measured and evaluated based on need satisfaction instead of merely using traditional economic and socio-demographic methods. The ERG model includes three groups of drivers, namely (i) trip efficiency improvement, (ii) social self-concept development and (iii) eco-travel promotion coupled with two groups of barriers, namely (i) perceived usage difficulties, and (ii) information privacy concern. The framework also includes environmental attitude in order to enhance our understanding of a wider set of motivators governing the user attraction and engagement. The environmental attitude incorporates the four dimensions of (i) personal conservation behavior, (ii) trust in travel information technology, (iii) human impact on environment, and (iv) environmental movement activism. The framework is evaluated using a case study in Copenhagen based on 828 respondents from a tailor-made questionnaire.

The results confirm the hypothesis that user attraction and engagement are associated with the ability of the travel app to satisfy functional and psychological human needs of relatedness and growth. Comparable to Noppers et al (2014), who investigated three groups of motivations for adopting sustainable innovations, we show that also for VTBC-based travel apps, the use intention is explained by functional, social and environmental motives. More specifically, a good evaluation of the ability of the app to improve trip efficiency leads to a good evolution of its social and environmental attributes and, in turn, translates into its adoption. Thus, the results support the hypothesis that the adoption of VTBC-based travel apps is not exclusively guided by their functional utility, but also by their ability to satisfy emotional needs by triggering feelings of sense of belonging, social identification and developing environmental self-identity, as well as eco-travel self-efficacy. Furthermore, the results show that the barriers embedded in the attributes of the travel app negatively influence its adoption. In other words, the study shows the need for consideration of reasons against, together with reasons for, in order to better explain the adoption of VTBC-based travel apps. Two dimensions that seem to have influence in the appraisal of acceptance of the app, relate with low usage risk and high usability. The findings also imply that environmental awareness, favorable attitude toward travel information technologies, performing conservation behavior, and a personal desire to participate in organized environmental activities affect individuals' perceptions of the benefits of the travel app and play a significant role in explaining their adoption decision formation.

Chapter 3 explores the underlying mechanisms of VTBC-based travel app users' behavior developed from the integration of Lindenberg's goal-framing theory and Bandura's triadic reciprocal determinism. In the decision making framework, users' motives to use the app are separated into three overarching categories of goals, namely (i) gain motives (e.g., time savings for travelling and information searching, effort savings for searching information and travel cost savings) (ii) hedonic motives (e.g., enjoyment and obtaining social approval), and (iii) normative motives (e.g., adopting environmentally-friendly travel behavior and contributing to the city CO2 emission reduction). The framework also includes technophile attitude as a personal factor reflecting emotional and cognitive attitudes toward using smartphone apps. To enrich the theoretical framework, we also incorporate the notion of "Community Resilience" including three groups of constructs, namely (i) institutional trust, (ii) social trust, and (iii)

place attachment. Using this, we address the critiques challenged persuasive technologies due to the sole focus on targeting specific behaviors and choices of individuals instead of proposing more collective approaches, which address the relevant communities that could have a higher impact on adoption. The framework is evaluated through a technology-use preference survey among 822 travelers in Copenhagen.

This study provides empirical evidence that user attraction and engagement relate to the efficacy of the travel app to satisfy functional and psychological human needs which agree with the results of Chapter 2. The results support, once more, the hypothesis that the use intention of VTBC-based travel apps is not merely relevant to their functional utility for improving trip efficiency. But also, it rests on their ability to satisfy emotional needs (i.e., by triggering feelings of enjoyment, sense of belonging and social identification), as well as to develop normative values. The results show that the higher level of gain motives are related to higher level of the use intentions, i.e. both adoption intention and situational use, whereas when it comes to hedonic and normative motives, this positive relation is conditional on travel purpose. Therefore, the loyal users of the app could be catheterized by being functionally motivated specifying the importance of the functional values of the system to attract and engage future users. According to the results, technophiles are an important target group of VBTC-based travel apps. They can play a significant role in promoting the use of this new generation of travel information system, thus contributing to rapid increase in demand. The results support that place attachment and trust ecology influence users' attitude and behavior. More specifically, an individual's motives toward the use of the travel app are highly relevant to the individual's general attitudes toward social trust, institutional trust and place attachment.

Chapter 4 replicates the second study with the data collected from Portugal in order to test the reproducibility of the effects obtained by Chapter 3 in a different country. This replication contributes to improve the current understanding of VTBC-based travel app adoption in a multicultural context due to possible cultural differences in perceptions. The framework is evaluated using a case study in Lisbon based on 227 respondents from a tailor-made questionnaire. We investigate the research hypotheses by applying Bayesian structural equation models (BSEM) since they are better equipped to model data with small sample sizes. We present two BSEMs, one with zero cross-loadings and a diagonal residual covariance matrix and the other with cross-loadings and correlated residuals, and evaluate which one fits the data better based on two indices for model fit and model comparison in Bayesian context. The results obtained from the later model support that both functional and psychological factors guide VTBC-based travel apps adoption in the same vein as previous findings in Chapters 2 and 3.

The results show that higher levels of gain and normative motives are both related to a higher level of the app adoption while it is opposite for hedonic motives. Therefore, the potential users of the app could be catheterized by being both functionally and normatively motivated not hedonically motivated. The strength of these effects indicates that gain motives dominate the adoption intention indicating the importance of the functional values of the system for users' attraction and engagement. This is in line with Chapter 3 supporting the domination of gain motives in users' behavior toward the adoption of

VTBC-based travel apps. As for the effect of technophile attitude and social dynamic behind the system, the results are compatible with the findings of Chapter 3.

The contribution of Chapter 5 is to examine the applicability of causal discovery methods to establish the associations between the constructs of a theoretical framework developed from Bandura's triadic reciprocal determinism. In other words, Chapter 5 studies the possibility of inference of an interpretable causal structure directly from data as to explain adoption intention toward VTBC-based travel apps with support in behavioral theories. It presents an initial attempt to apply causal discovery methods in travel behavior study. The constructs of the theoretical framework include the three groups of users' motives (i.e. gain, hedonic and normative motives), technophilia, and adoption intention according to the data description in Chapter 3.

The estimated causal structure shows that gain motives and technophilia have a causal effect on adoption intention. Likewise, there is a causal relationship from technophilia to both gain and hedonic motives. These findings agree with the self-efficacy based value adoption model suggested by Zhu et al. (2017) on the basis of Bandura's triadic reciprocal determinism. In line with the findings of the previous chapters, it once more highlights the importance of functional value of the system, as well as technology self-concept, as two important variables for the adoption intention. Furthermore, the results indicate the effect of technophile attitude on developing both gain and hedonic motives as discussed in Chapter 3. The causal structure shows hierarchical associations between the three groups of user's motive. They can be explained by the "frustration-regression" principle according to Alderfer's (1969) ERG theory meaning that a higher-level need remains unfulfilled, a person may regress to lower level needs that appear easier to satisfy.

6.3. Policy implications

The findings of this PhD dissertation draw several implications for policy and practice to foster users' attraction and engagement toward VTBC-based travel apps due to the diversity of influential factors identified and the different levels at which they operate.

The findings show the importance of higher-order needs in influencing the use of persuasive features of mobility-management travel apps. In other words, the satisfaction of non-monetary aspects of social self-development and eco-travel promotion motivate individuals to register for the environmental loyalty account. Hence, encouraging their development in relation to persuasive mobility tools may result in successful users' attraction and engagement. Self-monitoring, information sharing and gamification elements (i.e. incentives and rewards) appear to be considered as appealing persuasive strategies promoting and driving engagement, which should therefore be stressed throughout the process of system development, business design and marketing.

However, the results highlight the domination of self-interest motives of trip efficiency improvement for the adoption intention. Given the revealed insights into the interaction mechanisms of the persuasive solutions with travel behavior, the focus might need to shift from simply reducing or replacing car travel

demands by facilitating their adoption toward analyzing how they can improve individuals' travel efficiency by, for instance, providing accurate, informative and reliable travel information. Therefore, exploiting the potential of persuasive mobility-management solutions for trip efficiency improvement would be more promising in pursuit of sustainable transport planning.

In spite of prompting a growing interest in the application of ICT for sustainable transport planning, relevant policy actions do not sufficiently take into account the complexity of the interactions between ICT and travel behavior, and hence they tend to provide generalized strategies, procedures, and guidelines for the public. The findings of this dissertation present that users could exhibit different behaviors according to socio-economic characteristics, travel habits, attitudinal factors etc. Therefore, it is important to appreciate that "one-fit-all" actions without considering such heterogeneity might fail to address the diversity of behavioral responses, and accordingly cause inefficiency in policy. This PhD dissertation provides a good understanding of different user groups, which aspects of the technology they value and their corresponding motivations and barriers for their attraction and engagement. Therefore, for authorities and system developers, it is recommended to account for specific groups of users (e.g., young vs. old, technophile vs. technophobe, risk-averse vs. risk-taking attitude etc.), understand their needs and expectations, and provide appealing design from user's perspective since it will lead to motivating sustainable travel behavior. For example, the findings show that technophiles are an important target group of VBTC-based travel apps. However, the system attributes and functionalities should be aligned to the needs of both groups of technophiles and technophobes. In this context, on one hand, the entry threshold for unwilling users should be lowered (e.g. easy and understandable feature design) and on the other hand, tech-lovers should be appealed (e.g. providing the possibility of participatory design).

The results show the importance of pro-environmental attitude and responsibility since they not only develop non-monetary values of using mobility-management travel apps, but also foster users' engagement and attraction. Therefore, policies that provide sufficient knowledge about environmental issues and engender a sense of responsibility are effective to draw public attention to the prominence of their engagement for environmental and social benefits.

The findings also suggest the importance of social dynamic behind the information system, captured by place attachment and trust ecology, in influencing users' attitude and behavior. It indicates that public engagement is important in ensuring the success of the system implementation. It is essential to develop a meaningful dialogue between decision makers and the public as to create its public acceptance. The public dialogue should be rest on – and accompanied by – a robust communication strategy to understand citizens travel needs and expectations, clarify the need for change in their travel behavior and underscore the importance of their contribution.

6.4. Future research

While this PhD dissertation has considerably contributed to the knowledge about how to provide appealing ATIS from user's perspective and motivate behavior change in favor of sustainability, much

more research can be conducted in this direction. However, three main topics are worth highlighting on a general level.

Firstly, during the PhD study, the new travel app has not been operational. Hence, the study focuses on the pre-adoption stage. Future research should continue to investigate the post-adoption behavior and analyze the possibility of actual travel behavior modifications with the use of VTBC-based travel apps. Furthermore, it is important to employ panel studies allowing for evaluating the long-term effects of VTBC-based travel apps and their efficacy to sustain behavior change.

Secondly, this PhD study investigates user's perception and attitude toward the persuasive features embedded in the travel app as a package, i.e. being not completely segmented. Future research should also seek individual differences, which might lead to determine which user groups are most prone to be influenced by which persuasive feature. It will pave the way for an effective tailoring strategy.

Thirdly, there is some evidence showing that using mobile ICT devices while travelling creates a negative effect against sustainable mobility behavior. Julsrud and Denstadli (2017) showed that active users of smart devices are more likely to develop negative attitudes to public transport. Furthermore, the amount of time spent on the usage of ICT may induce more motorized travel demand, including by car (Hong and Thakuriah, 2016). We encourage future research to investigate such negative effects in relation to mobility-management travel apps.

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